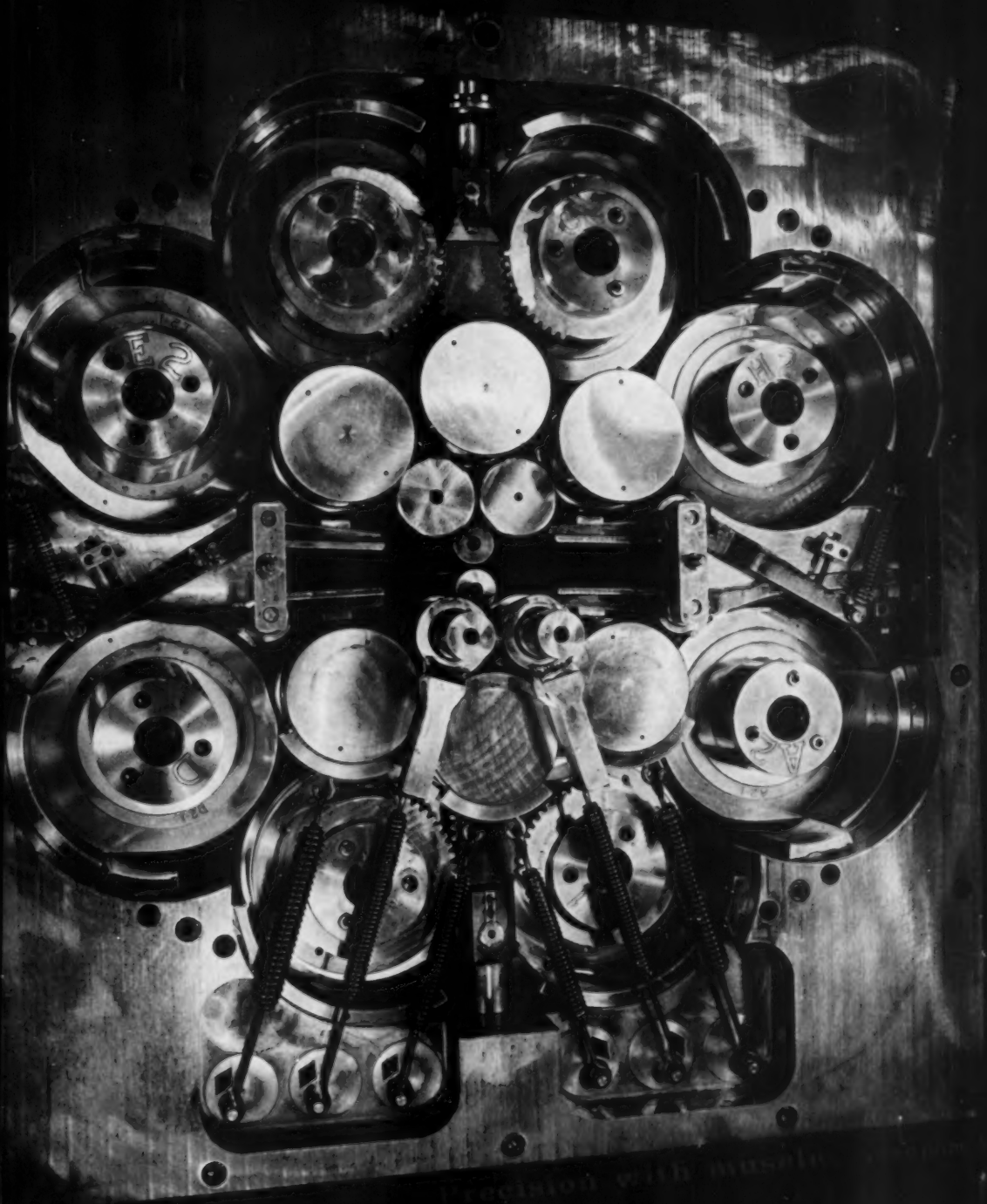
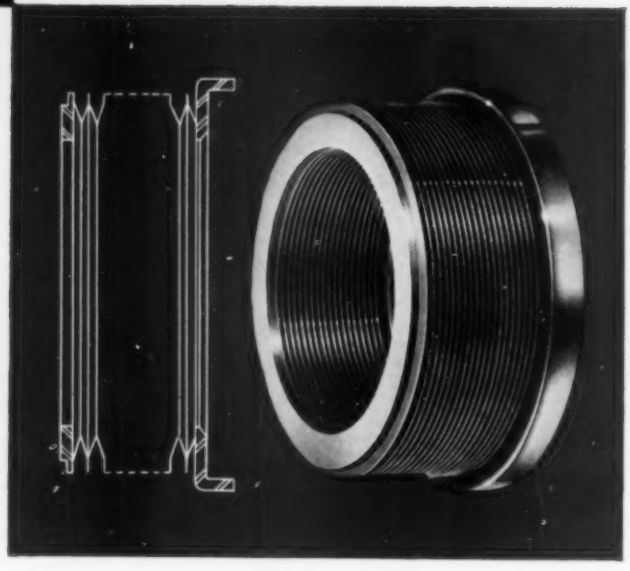
DESIGN issue

Product Engineering



C/R DESIGN NOTES

How C/R's New Metal Bellows Seal Meets Seemingly Impossible Operating Conditions



Operating Ranges

Temperature	−400° to 1000° F.
Pressure	500 psi
R.P.M.	80,000 plus

These known operating ranges indicate the function of this seal. It is designed for applications where temperatures and mediums to be sealed forbid the use of any organic materials. Typically, these applications include fuel pumps, compressor power units and turbine starters characteristic in rockets and missiles. Other applications include mechanisms which are exposed to a high level of radioactivity.

Design Advantages

The C/R metal bellows seal consists of a metal bellows — a welded homogeneous unit which is secured at one end — and a carrier ring in which the sealing face is mounted. The seal does not contact the shaft. It is stationary, and the only rubbing surfaces are the sealing face and mating ring. These surfaces are precision lapped to provide a positive seal with minimum friction. At any given pressure, the seal can be designed to maintain proper and constantly effective face loads. It orients immediately to run-out and will resist any torques it is subjected to in operation. The design has high end-play tolerance: Chicago Rawhide engineers have deflected a bellows .100 in. for three million cycles at 1750 cpm and at a temperature of 500° F. with no adverse effects.

A further advantage is relatively light weight and compactness. The C/R metal bellows seal can be designed for minimum axial and radial space. Axially, complete seals can be produced within a ¼ in. cross-section. Radially, dimensions are comparable with conventional end face seals.

The C/R metal bellows seal can also be designed with an extremely low coefficient of expansion. The importance of this factor becomes apparent with the fact that in many applications the operating temperature may change hundreds of degrees in a very few seconds.

Mediums To Be Sealed

Virtually any known liquid or gas may be positively sealed with this design, depending upon duration or service life. From a practical viewpoint, the C/R metal bellows seal is the best design for the sealing of cryogenic and high-energy fuels such as LOX, hydrogen peroxide, fluorine and other missile and rocket propellants.

Where possible, lubrication of the two sealing faces is desirable to prolong service life. However, the medium being sealed commonly acts as the lubricant and may be merely hot gas.

Materials

Sealing faces and mating rings for the C/R metal bellows seal are available in a variety of materials including carbons, carbides, ceramics and various alloyed metals for both high temperature and corrosion resistance. The bellows can be furnished in any of several metals and alloys such as stainless steel, Monel, Inconel X, Ni-Span C and other special alloy steels.

Consult C/R Engineers

Each application for the C/R metal bellows seal is essentially a custom-design and an intimate knowledge of all conditions to be encountered must be known by Chicago Rawhide engineers to produce the correct combination of properties in the seal. Then, whether you require five, fifty or five thousand seals, Chicago Rawhide will design and produce the correct seal to solve your problem.

Helpful Design Data:

We will gladly furnish you with a design guide and space envelope data concerning the C/R Metal Bellows Seal. Just write for Bulletin MBS-1 on your company letterhead.

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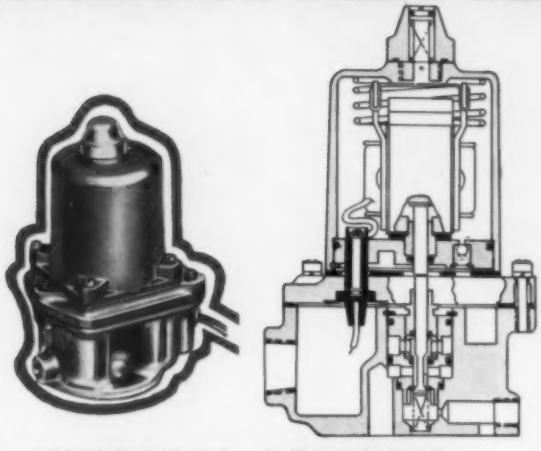
CIRCLE 101 READER SERVICE CARD

a basic Ross valve building block

GOLDMODEL VALVE HEAD



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- **The finest achievement in solenoid heads**
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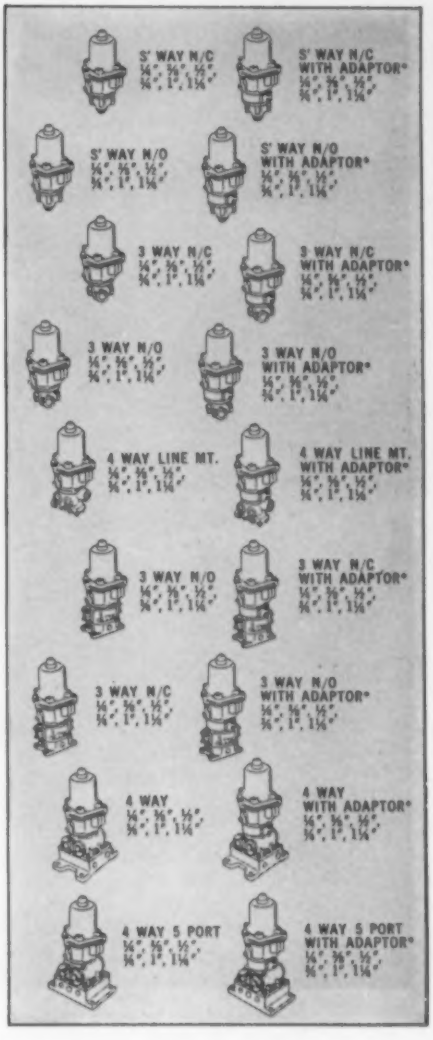
- **Over 50 million cycles in tests**
- **Lightning fast**

Modular construction is brought to the air valve field to give you the effect of a great valve inventory without stocking a great number of valves. Stock just one of these Goldmodel heads and you have the finest solenoid actuator obtainable for any one of the 54 Skyline bodies. This is the head designed especially for those uses where dependable performance and very long life must supersede all other considerations. The dustproof solenoid is the very finest and is immersed in oil to run cool and stay young. Write for bulletin 318.


5 WAY N/C
5 WAY N/C WITH ADAPTOR*
5 WAY N/O
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3 WAY N/C
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3 WAY N/O WITH ADAPTOR*
4 WAY LINE MT.
4 WAY LINE MT. WITH ADAPTOR*
3 WAY N/O
3 WAY N/C WITH ADAPTOR*
3 WAY N/C
3 WAY N/O WITH ADAPTOR*
4 WAY
4 WAY WITH ADAPTOR*
4 WAY 5 PORT
4 WAY 5 PORT WITH ADAPTOR*

WHITEMODEL SPOOL SOLENOID
WHITEMODEL SPOOL SOLENOID MOMENTARY ADAPTOR
"featured above"
GOLDMODEL OIL IMMERSED SOLENOID
GOLDMODEL OIL-IMMERSED SOLENOID MOMENTARY ADAPTOR*
SILVERMODEL JIC SPOOL SOLENOID
SILVERMODEL JIC SPOOL SOLENOID MOMENTARY ADAPTOR
GREENMODEL DOUBLE SOLENOID MOMENTARY
BLUEMODEL AIR OPERATED
BLUEMODEL AIR OPERATED MOMENTARY ADAPTOR
BLUEMODEL AIR OPERATED TIMED IN
BLUEMODEL AIR OPERATED TIMED OUT

"every head meets every body at this gasket"

ALL SKYLINE HEADS AND BODIES ARE BUILDING BLOCKS TO GIVE YOU MANY VALVES FROM A FEW HEADS AND BODIES

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3 WAY NORMALLY OPEN NORMALLY CLOSED
4 WAY
3 WAY NORMALLY OPEN NORMALLY CLOSED
4 WAY
4 WAY 5 PORT

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CIRCLE 104 READER SERVICE CARD

Streaking down to earth from space, X-15's skin of Inconel "X" alloy will glow with the dull cherry red of a tossed rivet. X-15, the first manned space-probe ship, is built by North American Aviation, Inc.

How X-15 survives red-hot re-entry

When the first manned space-probe ship, X-15, streaks in from space to re-enter the earth's atmosphere, air friction heats its nose and leading edges to a dull, glowing red in seconds.

Temperatures as high as 1000°F build up. Temperatures that could easily weaken the skin of the X-15. Temperatures that *melt* aluminum. *Deform* carbon steels. *Destroy* most other materials.

How could designers make it possible for X-15 and her pilot to return safely?

The answer was found in the high-temperature properties of Inconel "X"*, an age-hardenable nickel chromium alloy. Inconel "X" alloy offers the high-temperature strength X-15 needs to make its red-hot comeback into earth's atmosphere.

Does this versatile alloy suggest a way you can get some problem facing you off the ground? Inconel "X" alloy provides good spring properties as high as 1000°F. Its relatively low coefficient of expansion makes it useful for parts which must move within tight clearances at high temperatures. And its oxidation and corrosion resistance at high temperatures are outstanding.

If your design problem involves high or low temperatures, corrosion, stress, fatigue . . . or perhaps a combination of these conditions . . . talk it over with us. One of the versatile Inco Nickel Alloys may be able to bring one of your designs back "home" safely and economically. Write for our new booklet, "High Temperatures Spur Use of Nickel-Base Alloys" for "red-hot" information. It's yours for the asking.

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Product Engineering

McGRAW-HILL MAGAZINE OF DESIGN RESEARCH AND DEVELOPMENT

DESIGN issue

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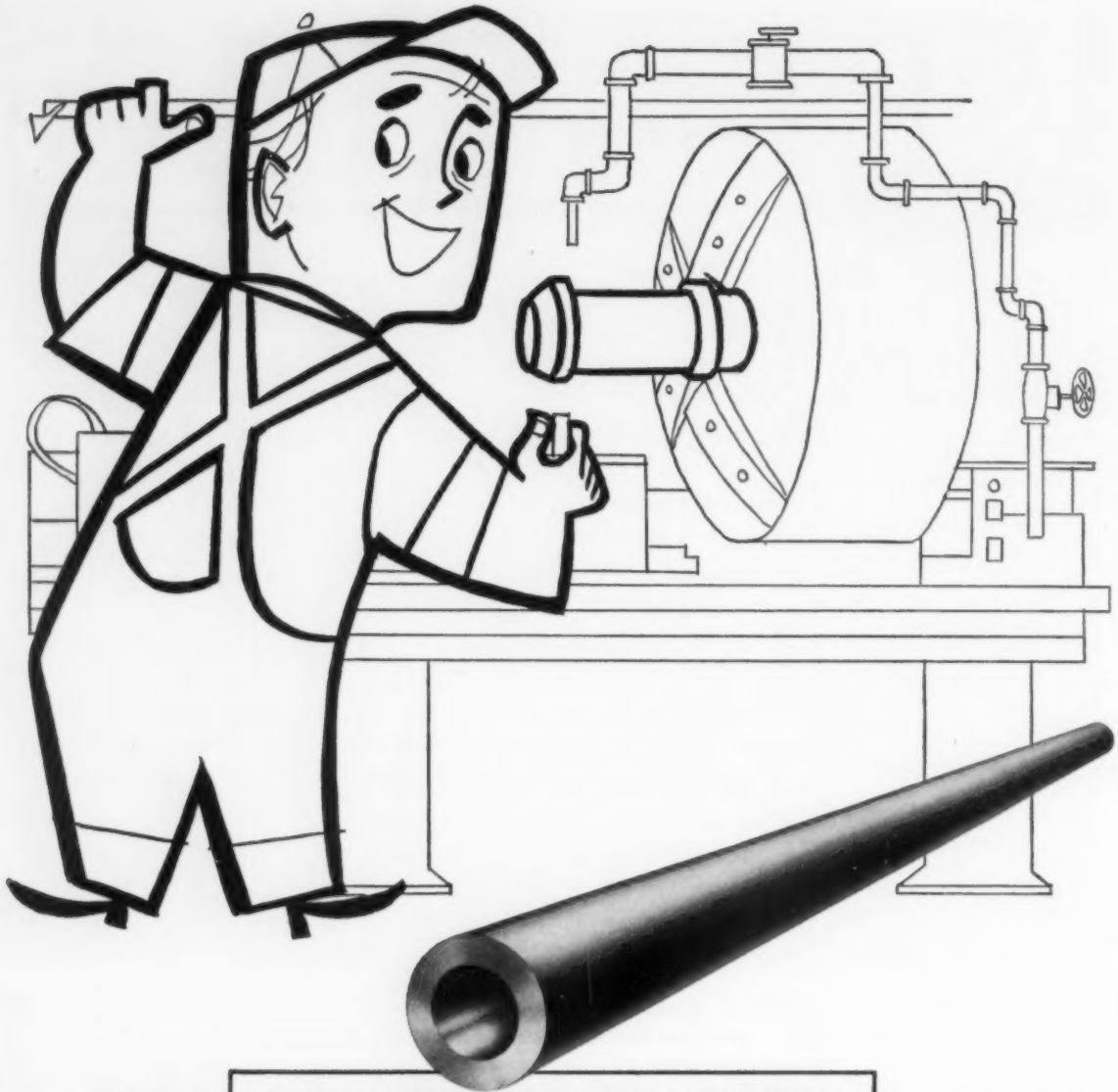

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Interesting to Note . . .

Sendzimer's Mill

A major development in the steel industry usually costs money, and plenty of it. Therefore, in 1942, when Tadeusz Sendzimer wanted to convince the chief engineer of a Canadian steel company that his idea for a planetary rolling mill would work, he had to be sure himself before he could start talking dollars. Sendzimer made himself so sure that in his preliminary talks, he said casually, "With this mill, I can reduce a 2¼-inch slab to one-tenth inch in one pass." Normally, such a job would take at least eight passes.

Unfortunately, the war halted Sendzimer temporarily, but in the fall of 1951 the Canadian company agreed to give the new-mill idea a try. The first cost estimate was $320,000, which later proved to be $100,000 too low. By the time all the buildings were constructed and the equipment was assembled the price was up to $1.5 million. In 1954 everything was ready to roll. The company's chief engineer recalled, "When those rolls took their first bite, the noise was like a 50-caliber machine gun cutting loose inside a boiler, but the slab went through without a hitch. But that mill wasn't shaking any worse than I was." Success of Sendzimer's mill is evidenced by the number of others now installed in plants throughout the world. Our cover shows such a mill now in operation at the Jones and Laughlin Steel Co.

Dragon Drums Up Business

During the Battle of the Bulge, the Nazis tried the trick of sending captured allied tanks, vehicles, guns and even English-speaking German soldiers, dressed in captured uniforms, into the fight. Their plan backfired as soon as the GI's saw them coming. When the German's relabeled the vehicles for their own identification purposes, they employed their own style of letters and numbers, which were immediately distinguished from the standard stencils used by the US Army. Knowing how, where, or when to label is not a problem common just to the military. The article on page 55 tells the designer what he wants to know about labeling his products.

Sometimes a little psychology is needed in choosing the right label. A British welding firm, Quasi-Arc Ltd, wanted to market electrodes in Hong Kong. When the company's name appeared

(CONTINUED ON PAGE 7)

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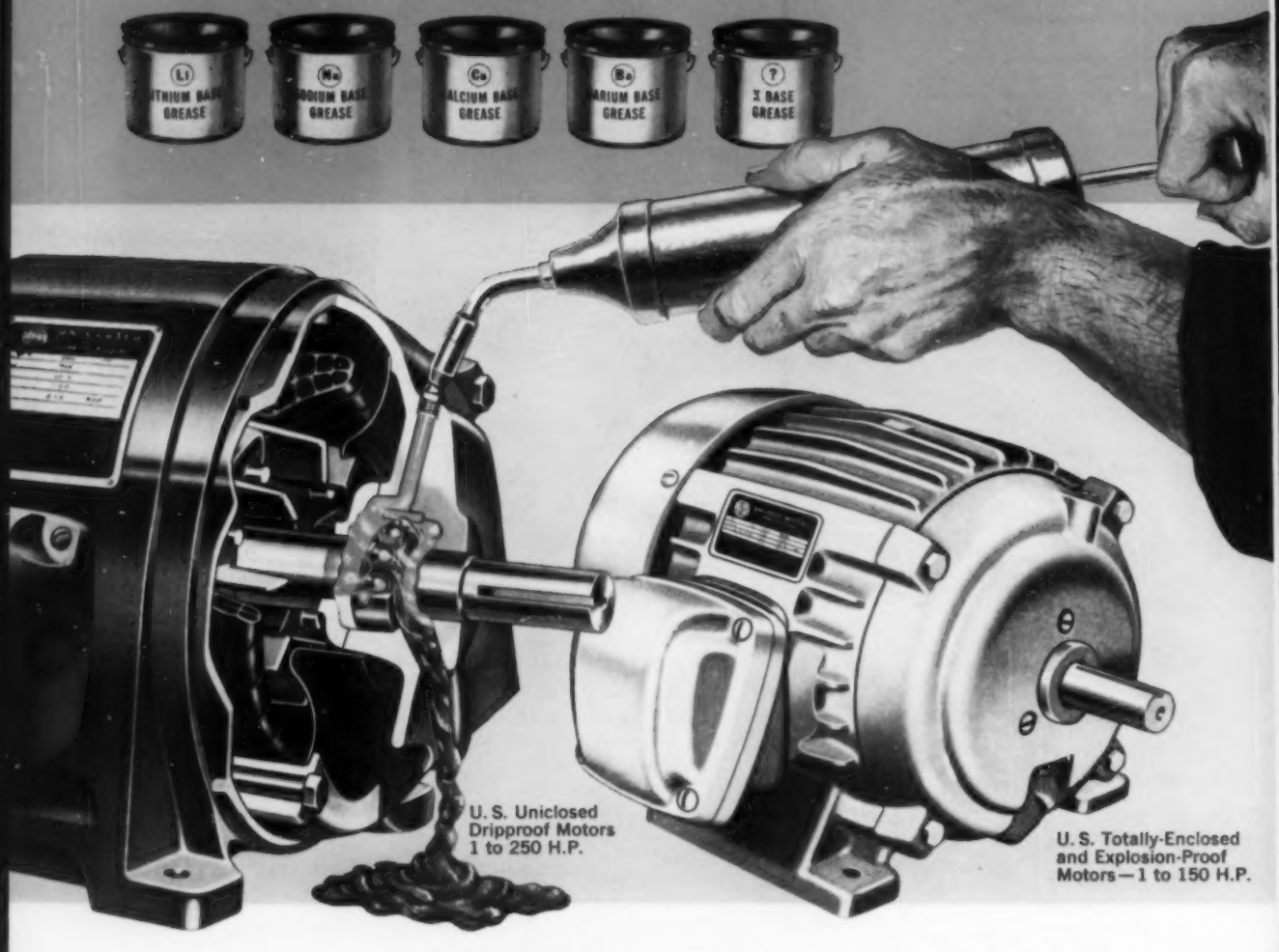

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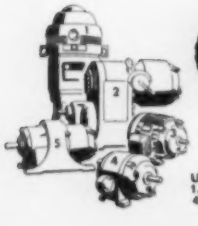

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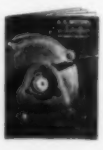

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on the product it meant nothing to that island's Chinese. The company decided to phonetically spell Quasi-Arc in Chinese characters on each electrode. Still the Hong Kongers weren't told. Too many local dialects plus lack of product identification kept customers from buying.

Then someone hit on the idea of substituting a symbol for a name. The symbol: a red dragon. Now everybody's happy. Customers who couldn't cope with Quasi-Arc now confidently ask for "red label dragon electrodes."

With This Shoe, I Thee Wed

Man first put a crude covering on his feet to protect himself from the elements and, ever since, the primary purpose of shoes has been for protection. Even industry has adopted the term "shoe" as a word meaning protective covering. Brake shoes, for example, are found on automobiles as well as some heavy machines. While early footwear was largely functional, it was nevertheless a mark of social position as well. Slaves went barefoot while a person of position wore shoes. Our earliest known foot coverings were the Egyptian sandals made by slaves.

Mere fact of shoe ownership did not satisfy the pride and vanity of the upper classes. Decorative features were added to shoes in the form of precious stones and metals. Soon colored leathers and fabrics were introduced, and shoes became objects of adornment as well as function. In many cultures, shoes became symbolic. Young men of ancient Hebrew civilizations gave their brides-to-be not only rings but also shoes to symbolize mutual possession of worldly goods. Not to be outdone, the girls had their lovers' names engraved on metal plates and fastened on the heels of their shoes. As the maiden walked, her lover's name was imprinted in the sand.

Scientist in the Gym

Of all the ways to develop a new concept, perhaps most frustrating is the laborious procedure of trial and error. When Edison was working on his incandescent lamp, he literally had to test over 6000 different vegetable fibers before he happened across one that wouldn't blacken the interior of his glass bulb. One of Edison's assistants in this work was Norman Mellor, a man who soon would go through the same sort of trial and error to find the right substance to fit a unique experimental need of his own.

This was after Mellor left Edison in 1891 and took a job at the Electric Storage Battery Co. He worked in the lab during the day and sought relaxation in his local gymnasium in the evenings. In the gym there was one piece of exercising equipment that bothered him—a weighted rope that ran over a pulley kept squeaking everytime he pulled the rope. Why couldn't somebody develop a wooden bearing that wouldn't squeak? For the next four years Mellor worked on the problem—to find a wood which could be permanently impregnated with a lubricant. Then he'd have his non-squeaker.

He began by trying to impregnate some of the common species of wood. Nothing seemed to work. He imported some wood in the hope that by sheer trial and error he'd find the answer. After trying more than 600 different types of wood, Mellor at last succeeded. He found he could impregnate wood from a maple-like madrona tree with his secretly developed lubricant.

This quest for a better pulley in a gym led to answers for many industrial needs. By 1896 Mellor had a plant and four employes turning out oilless wood bearings. Now this company, Arguto Oilless Bearing Co, is headed by Mellor's son and employs about 120 persons turning out screw conveyor hanger bearings, conveyor roll bearings and standard cylindrical bearings—to name a few. Their newest development, an oilless plastic bearing, is described on page 58.

Juvenile Gunsmith

When Eliphalet Remington's father wouldn't give him the money to buy a new rifle he decided to make his own. Today he'd probably be called a juvenile delinquent, but in 1816 if you couldn't buy a gun the only choice open was to build one yourself. His first task was the forging of metal parts to exact dimensions, then the stock was gracefully formed from wood of his own hewing and seasoning. This complete, young Remington faced a major obstacle—tools to straighten the barrel, like the modern tube-straightened described on page 49, and implements needed for rifling the barrel were not available in his father's workshop. Undaunted, Remington walked to Utica, 15 miles from the farm in Ilion, NY; there an experienced gunsmith "rifled" the barrel for him.

Now the finished and tested rifle was taken to a neighborhood shooting match. A marksman of little experience but no mean ability, Remington was defeated only by the champion of the area. So impressed by the accuracy of the rifle were the spectators and contestants that Remington was beseiged by requests for guns.

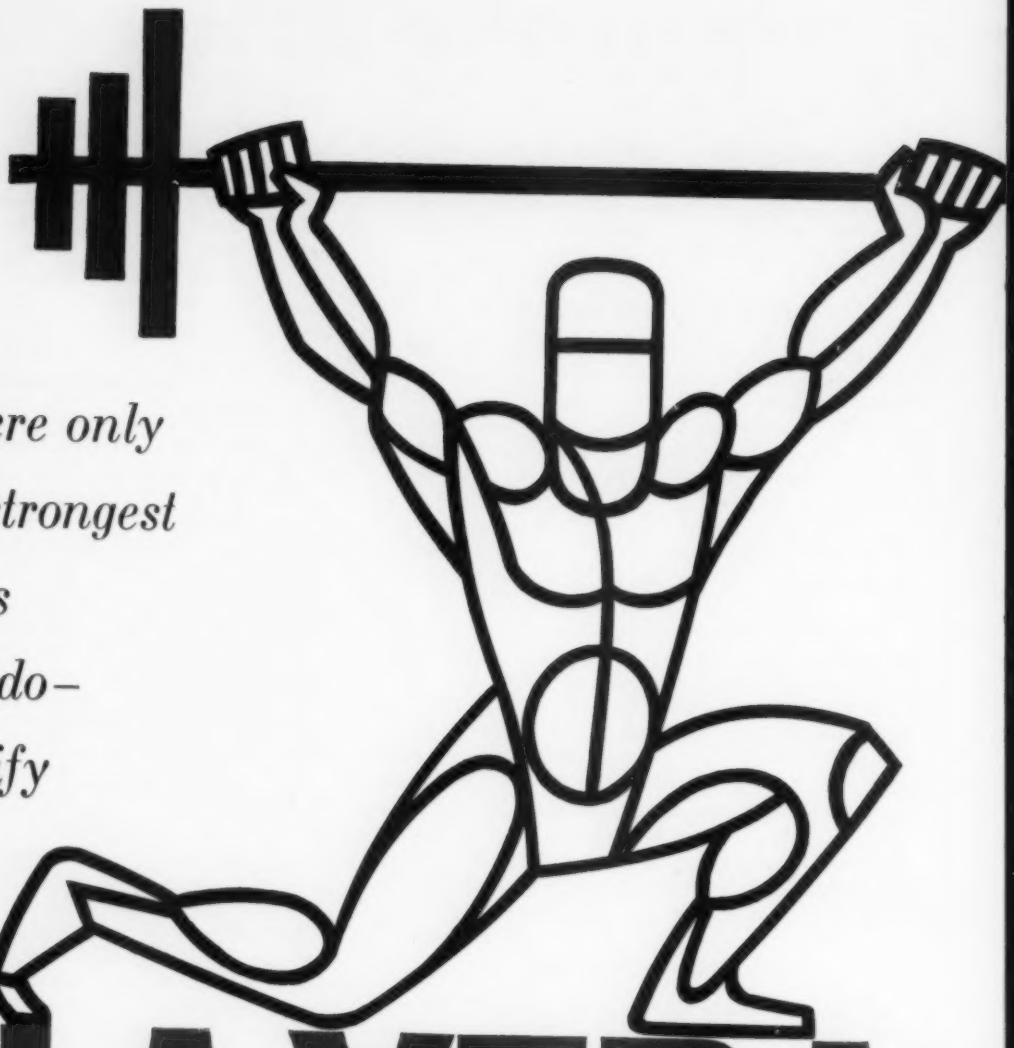
Soon he built his own shop and began designing his own machinery. To meet the quality demand of customers in his new plant the old lap-welded barrel gave way to the barrel drilled from solid steel. Thus was founded a great arms company that would bear Remington's name.

—Benedict A Leerburger Jr

Our Apologies

Through a regrettable omission in our item on the attractive April 27 cover, "Stainless grows whiskers," we failed to include information on the source for the unusual color transparency as well as the occasion for the picture. The color photograph was taken during a study of stainless oxidation conducted by Dr Earl Gulbransen of the Westinghouse Research Laboratories. The reproductions were made by the dye transfer method using black and white negatives taken through an electron microscope and then tinted to true color.

These color photographs were produced by O M Forkert Associates and then reproduced for printing by a 4-color engraving process. The clean simplicity of the final reproduction gives no clue to the high level of skill and technique involved in these three successive stages of: electron microscope negative, dye transfer, and 4-color engraving. But the results attest the skills applied.



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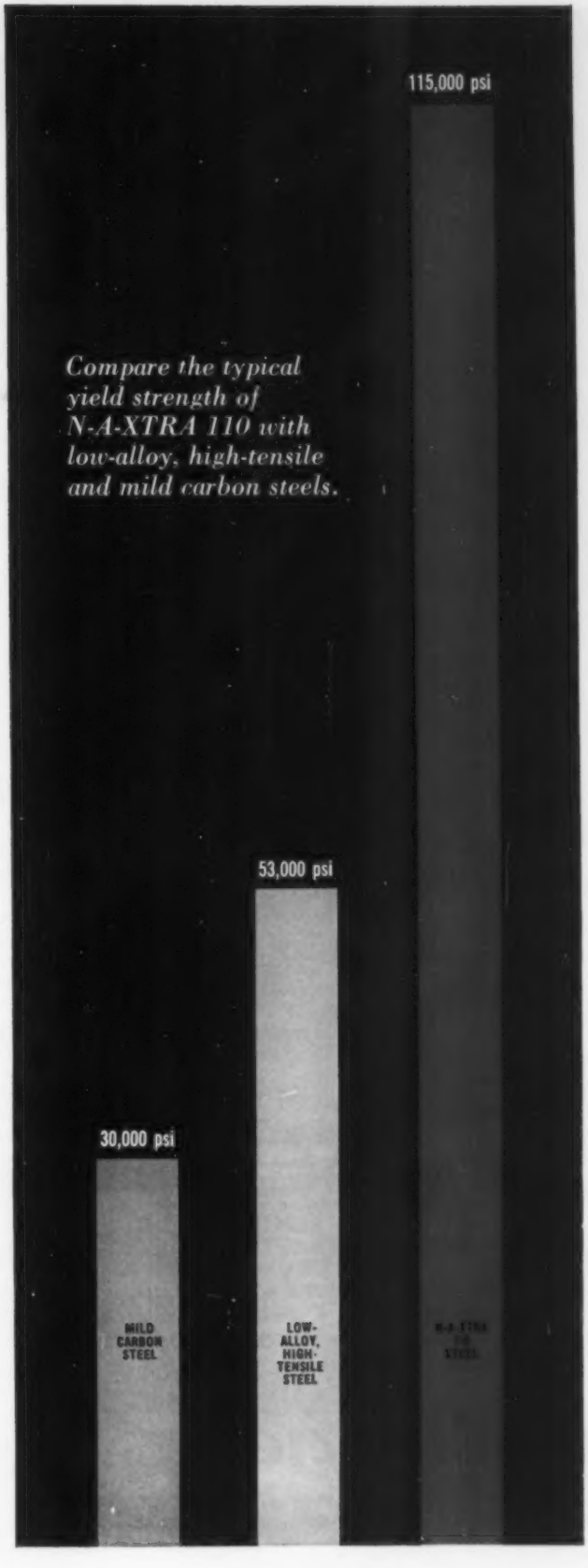
115,000 psi
Compare the typical yield strength of N-A-XTRA 110 with low-alloy, high-tensile and mild carbon steels.
53,000 psi
30,000 psi
MILD CARBON STEEL
LOW-ALLOY, HIGH-TENSILE STEEL

Now available, N-A-XTRA HIGH-STRENGTH is a low-alloy heat-treated steel, fully quenched and tempered. The minimum yield strength range of N-A-XTRA steel is from 80,000 to 110,000 psi.

The great strength of N-A-XTRA (nearly three times that of mild carbon steels) gives designers the opportunity to eliminate costly dead weight from your products.

N-A-XTRA is tough at normal and subnormal temperatures. It can be readily cold formed into difficult shapes. And it welds beautifully by any process—with no underbead cracking. For a job where only the strongest of steels will do . . . specify N-A-XTRA HIGH-STRENGTH steel.

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A DIVISION OF NATIONAL STEEL CORPORATION

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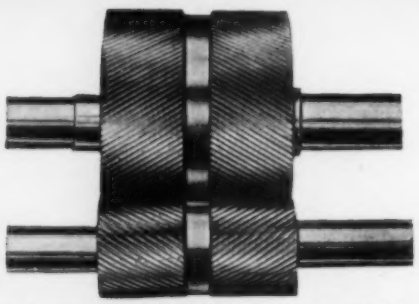
It is axiomatic that "no gear can be any more accurate than the machine on which it is made" . . . to this end we have continually installed the most modern and accurate gear machinery for producing all types and sizes of gearing . . . these machines are operated by skilled gear craftsmen . . . but even this is not enough at Phillie Gear, for all gears must be checked and analyzed on the latest testing machines. *There's no compromising with Quality at Phillie Gear.*

Indicative of the standard of precision required of our manufacturing equipment is the gear hobber shown above. This machine has a special high accuracy table drive which is maintained accurate within 20 arc seconds. This accuracy is significant in consideration of the fact there are 1,290,000 arc seconds in a circle.

When you think of gears—think of Phillie Gear. Write for a free copy of our 76 Page Gear Book—a complete data book on all types of gears.



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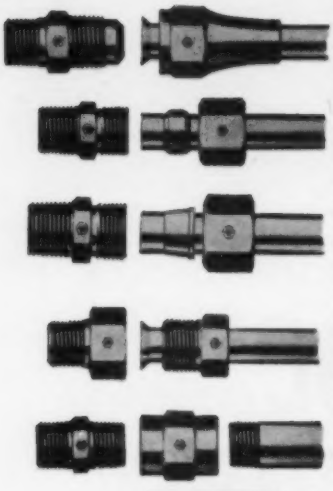

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USE with copper, brass, aluminum, steel and plastic tubing. U.L. listed; A.G.A. approved. Meets SAE Hydraulic standards and A.S.A. and A.S.M.E. codes. PRESSURE RATING: up to 3000 p.s.i. Sizes: ⅛" to ¾".

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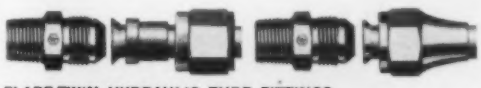

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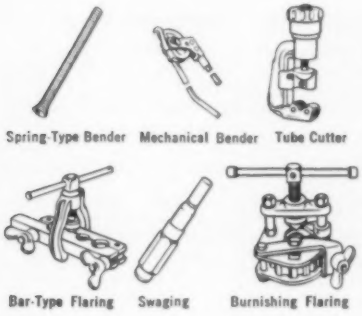

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ALLEN-BRADLEY
Solenoid Starters give

MORE MILLIONS OF TROUBLE FREE OPERATIONS

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• ONE MOVING PART
With this simple solenoid design, there's virtually nothing to go wrong—all trouble-causing bearings, pivots, and flexible jumpers have been eliminated.

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Allen-Bradley silver alloy contacts never require maintenance. They are always in perfect operating condition . . . and remain so until completely worn away.

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• RELIABLE OVERLOAD PROTECTION
All A-B starters are equipped with two permanently accurate and reliable overload relays that protect motors against "burnouts." Three overload relays can be furnished.

BULLETIN 709 STARTERS are made in 9 sizes from Size 0 (at left) up to Size 8.

BULLETIN 709 SIZE 7 with maximum ratings of 300 hp, 220 v; 600 hp, 440-550 v.

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To be positive that GRAMIX products of powder metallurgy will function in any given application in the most efficient manner possible, The United States Graphite Company *engineers* the alloy so that it meets exact physical properties required in the application. And, in addition to engineering the alloy to the application, every step in the manufacturing process is rigidly controlled. Correct compacting, controlled sintering procedures and precise finishing operations contribute to the dependable performance of GRAMIX parts.

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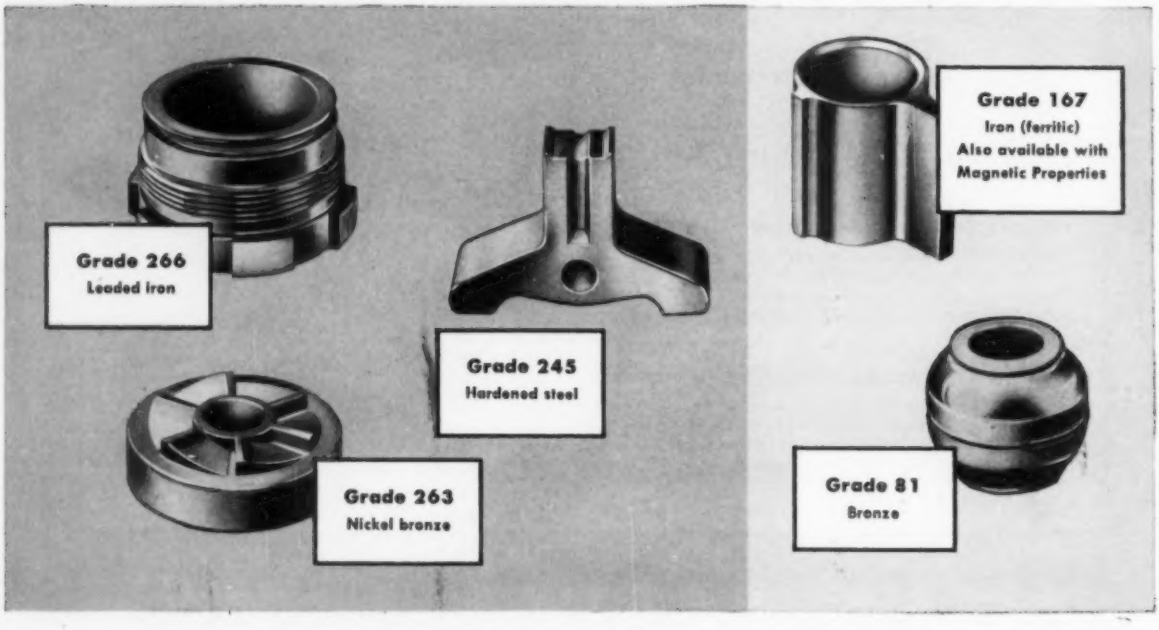
Write today for these helpful engineering manuals. Engineering Bulletin No. 18 covers design and metallurgical requirements and alloy selection of GRAMIX bearings. No. 19 contains facts about GRAMIX Machine Parts and No. 21 contains general information on GRAMIX products from Powder Metallurgy. Get your copies now.



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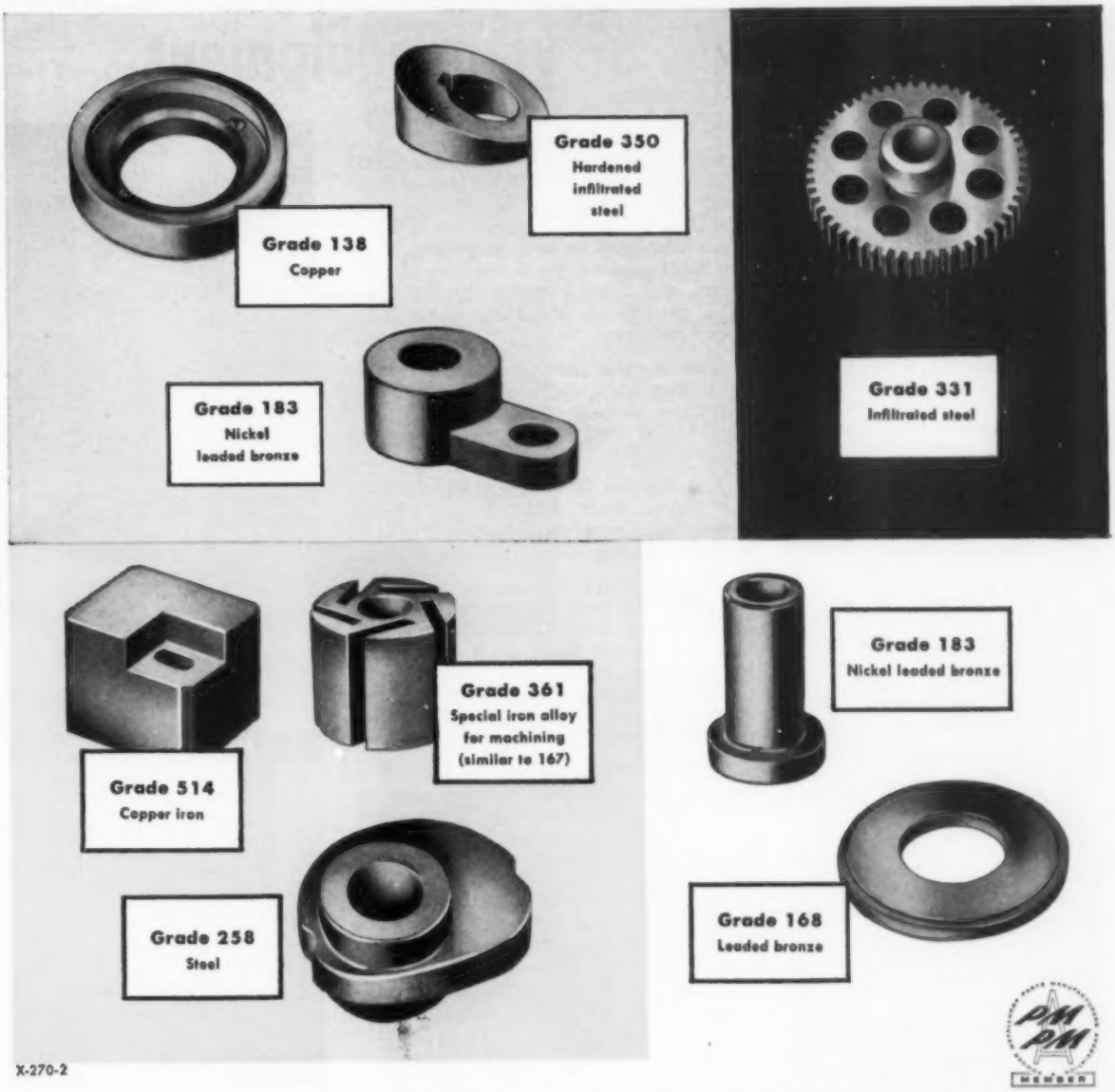

X-270-2

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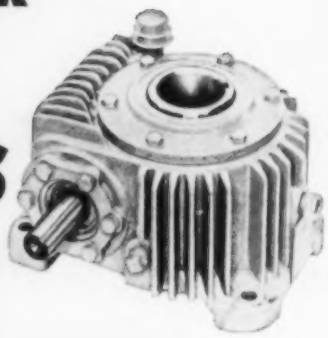
GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW 12, MICHIGAN

CONE-DRIVE WORM GEAR HOLLOW SHAFT SPEED REDUCERS



provide greater flexibility in the design of your equipment

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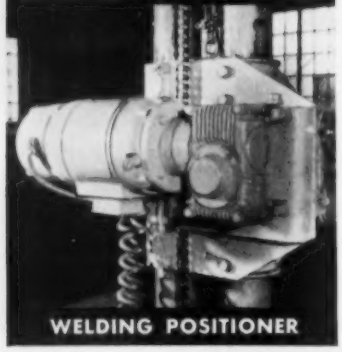

WELDING POSITIONER

Standard Cone-Drive hollow shaft speed reducers are available in four basic sizes (2, 2½, 3 and 3½ inch center distance units) to accommodate loads from fractional to 13 horsepower. They are built around the double-enveloping worm gear design and carry the same high ratings as standard Cone-Drive speed reducers.

You, as a designer, will be particularly interested in the versatility of application and space savings made possible by the right angle design between input and output shafts.

The reducer is mounted directly on the driven shaft and requires only a simple bracket or torque arm to prevent it from rotating about the driven shaft.

Construction is rugged enough to permit floor or wall mounting of Cone-Drive hollow shaft reducers and "hanging" the driven shaft on it (in certain applications), eliminating pillow blocks or bearings. Larger-than-necessary taper roller bearings and heavy-duty castings make this possible.

If a motorized reducer is desired, a simple, standard bell housing can be furnished for NEMA C-type face motors. The need for expensive couplings is eliminated since a tang-type drive sleeve and suitably machined worms are provided. When a hollow-shaft speed reducer and face-mounted motor are combined, no bed plate or mounting arrangement is required. Pulleys, belts, sheaves, etc., that might be troublesome or difficult to install are also eliminated.

Ask for Bulletin CD-218.

TROLLEY HOIST

MILL ROLL DRIVE

LAUNDRY MACHINE

CONE-DRIVE GEARS DIVISION MICHIGAN TOOL COMPANY

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DOUBLE-ENVELOPING WORM GEARSETS

DOUBLE-ENVELOPING WORM GEAR SPEED REDUCERS

DOUBLE REDUCTION WORM GEAR SPEED REDUCERS

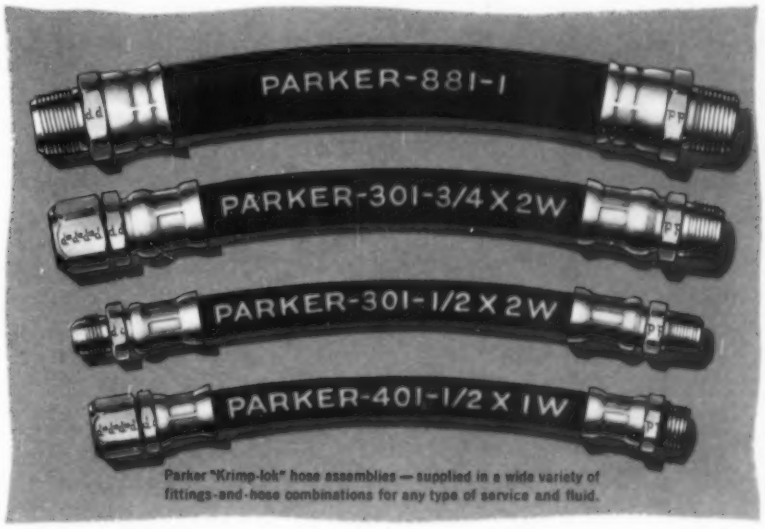
DOUBLE-ENVELOPING RIGHT ANGLE GEARMOTORS

Now from Parker

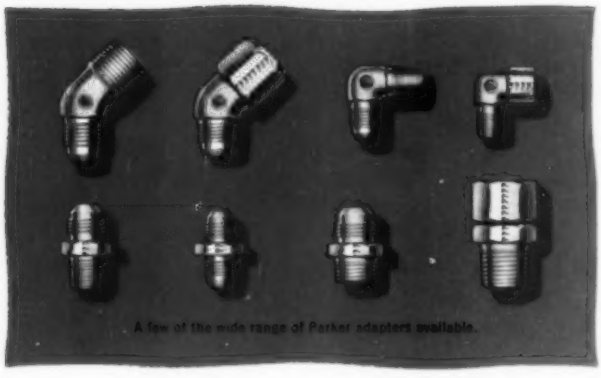
BOTH permanent-end

and re-usable

hose assemblies



Parker "Krimp-lok" hose assemblies — supplied in a wide variety of fittings-and-hose combinations for any type of service and fluid.


A few of the wide range of Parker adapters available.

You may require permanent-end hose assemblies for your production AND re-usable fittings with coils of hose for quick, trouble-proof replacements in the field. With the addition of Parker's new "Krimp-lok" fittings, permanent-end assemblies are now available from Parker. They use the same Parker hoses that enjoy a wide acceptance when used with Parker *no-skive* "Hoze-lok" fittings in the replacement field.

A full range of Parker adapters is also available.

Ask your Parker Hose Distributor, listed in the Yellow Pages, for engineering advice and literature on "Hoze-lok" re-usable fittings, also Parker hose and adapters. Write us in Cleveland regarding your requirements for Parker "Krimp-lok" Hose Assemblies.

Parker

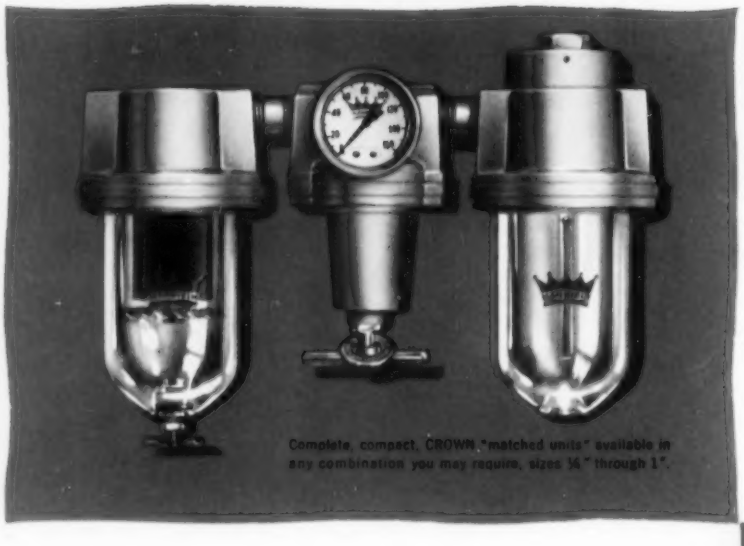
FITTINGS AND HOSE

DIVISION

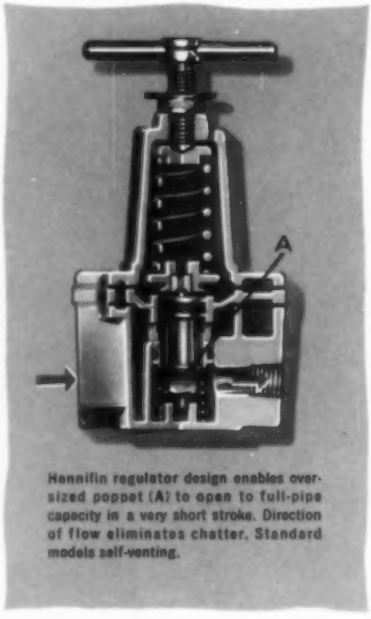
17325 Euclid Avenue

Cleveland 12, Ohio

Crown From HANNIFIN air preparation units that don't waste air power



Complete, compact, CROWN "matched units" available in any combination you may require, sizes ¼" through 1".



Hannifin regulator design enables oversized poppet (A) to open to full-pipe capacity in a very short stroke. Direction of flow eliminates chatter. Standard models self-venting.

Hannifin CROWN "Combo" units – filters, regulators and lubricators in any combination – keep compressed air in the "pink of condition" without depriving you of needed air flow.

Crown regulators open fast on demand, close precisely when demand is satisfied, deliver the exact amount of air needed. Their "piston balanced" poppet design, which makes possible a flat, large-area, poppet-type valve with very short stroke, is the reason. The inherent stability of this design – no hunting or chatter – results in multi-million cycle life.

Crown filters have large, reusable filter elements for minimum resistance to air flow. Crown lubricators introduce predetermined amounts of oil into the air stream, automatically. Their design is so responsive to variations in air flow rate that the concealed, tamperproof adjustment is rarely used. This is the easiest lubricator of all to fill, and remote-fill models are available.

Crown units are competitively priced and stocked in principal industrial areas by Hannifin CROWN authorized distributors. For CROWN literature and the name of the distributor nearest you, write:

HANNIFIN COMPANY

535 South Wolf Road • Des Plaines, Illinois

Lubricator vane (A) is factory pre-set for most applications. Valve (B) shuts off air pressure to bowl when fill plug is removed. This patented Hannifin feature permits bowl refill without shutting down air line.

DEVELOPMENTS TO WATCH...

Modulated-air speakers are moving . . .

. . . into a host of specialty devices for such wide-ranging applications as metallurgical testing and air pollution control.

Big advantage of these speakers and sirens which operate on a principle similar to that of the human voice is that they provide more noise per pound (more intelligible, too) than conventional devices which operate by electrical vibrations.

Stanford Research Institute, has been working on airstream modulators for some time, and now reports that one such unit has been incorporated in a completely self-contained system, adaptable for air transportation and parachute delivery, that will operate by radio or tape recording and weighs barely 100 lb. That's less than one-sixth as much, SRI says, as a conventional unit would. It doesn't even need an air compressor. It uses a solid propellant hot gas generator (*PE*—Jan 6 '58, p 56) as a power source.

Now under development are units to produce high-energy vibrations for fatigue testing and chemical processing. Eventually, SRI suggests, it might even be possible to produce an air-stream modulator that could be hooked up to auto muffler to remove smog-producing particles from exhaust gases.

Slimmer belts can be used with standard drives . . .

. . . and outstanding performance obtained with smaller sheaves by taking advantage of its newest V-belt design, says Manhattan Rubber Div, Raybestos-Manhattan, Inc.

Especially designed for high-speed, small-pulley power transmission systems, the Poly-V "J" is said to operate over sheaves as small as 0.8 in. dia. It is thin, flexible, has parallel V-ribs molded lengthwise around its inside circumference to mate with grooves in the sheave so that load is evenly distributed. Other advantages claimed for the new belt: small mounting clearance and takeup requirements, overload slip protection, and good resistance to heat and oil.

Manhattan Rubber will soon make the belts available to original-equipment manufacturers.

Compounds that can "solubilize the insoluble" . . .

. . . are being developed by Foote Mineral Co. These are lithium inorganics which, the company says, would permit new combinations of inorganics and organics for specialty lubricants, wetting agents, and the like.

Also under development are lithium glasses with "substantially lower melting temperatures" and "better chemical durability"; a new highly-reactive lithium hydride; and new lithium catalysts for synthetic rubber.

Milk-fed heat pump system . . .

. . . developed for the US Dept of Agriculture at the State College of Washington uses the waste heat energy in milk to preheat water for washing milking equipment.

As agricultural engineer M. C. Ahrens points out, the heat removed from milk in the cooling process may not seem very great, but a tank cooling 200 gallons of milk a day will pump out heat energy equivalent to more than 9000 kwh of electric energy during a year.

In the test setup pictured here, a 400-gal. bulk milk tank is used with a 2-hp refrigeration unit, directly connected to a circulating pump that carries the heat energy through a solenoid-controlled, water-cooled condenser. Warm water from the condenser is fed into the top of a 42-gal. preheat tank, from which supply water (heated from 55 to 120 F) is drawn for storage in a conventional electric water heater.

In experimental heat pump installation, raised milk tank has voltage recorders, circulating pump and compressor mounted beneath it. Bulk milk cooler is at lower left; preheat tank against wall in center; water heater at right.

DEVELOPMENTS TO WATCH...

Best protective coating for temperatures to 930 F . . .

. . . may turn out to be an aluminum-silicone paint. Air Force-sponsored studies by Metcut Research Associates of high-temperature coatings for chromium hotwork tool steels indicate paints of this type provide good protection against corrosion without sacrificing other desirable characteristics.

Hot-dipped and electrolytic coatings tested by Metcut show specific advantages (electroplated nickel had high thermal resistance, for instance; and electroless nickel had the best abrasion resistance); but also some serious limitations. For example, Metcut says, the high temperatures involved in depositing some hot-dipped coatings can significantly reduce fatigue strength of the base metal.

The Metcut report has been released by the Air Force, and will shortly be available from Office of Technical Services, Department of Commerce, Washington 25, D. C. It is a 90-page publication which has been given the number 151 423; its price will be $2.25.

Best bearing steel for the 930-F range . . .

. . . is a complex alloy with a carbon content of 1.09 and approximately the following composition: Cr, 4.2%; V, 1.9%; W, 6.7%; Mo, 3.7%; Co, 5.2%.

That's the opinion of Crucible Steel metallurgists after an exhaustive study of 51 experimental compositions. In a report to Wright Air Development Center, soon to be published by OTS (see below), they say a steel of this composition, austenized at 2225 F, oil quenched, and tempered for two consecutive 2-hr periods at 1050 F, produces a material which can do the job, as considered from the standpoint of hot-hardness, dimensional stability, compression strength, oxidation resistance and hot oil corrosion resistance.

This report has not yet been released, but has been assigned a publication number (PB 151 415), and is expected to be available soon from Office of Technical Services, Department of Commerce, Washington 25, D. C. It is a 63-page report; will be priced at $1.75.

New test equipment will be needed . . .

. . . before many products designed for the 930-F range can be fully evaluated. Research like that described above, and such products as "red-hot motors" and ceramic electron tubes are demonstrating that this operating range is far from a pipe dream. But, as Navy researchers point out, present-day equipment designed to test electrical and other properties just can't stand the gaff. For instance, materials now used as sample-supports during electrical resistance tests on insulating materials will have to be replaced by new ones better able to serve at very high temperatures; or entirely new methods of support will have to be devised.

Though it's likely to be some time before 930-F products are ready for operational use, Navy test centers are moving ahead on equipment development, so that test systems will be available when the products themselves come rolling out of the lab.

New explanation of stress corrosion cracking . . .

. . . comes from C. Edeleanu of Tube Investments Research Laboratories, Essex, England.

In a report prepared for the Metallurgical Society of the AIME, and soon to be published by Interscience Publishers, he suggests the cracking is a two-stage, repetitive process involving chemical and mechanical action. But, he notes, the chemical reaction is "much more subtle than the simple dissolution of metal," and takes place at a relatively slow rate compared to the mechanical portion of the process. This seems to tie in quite well with recent findings in this country.

N. A. Nielsen of DuPont's Engineering Research Laboratory reports that, in transgranular crack propagation in austenitic stainless steel, cathodically deposited corrosion products may exert a simple wedging action on the apex of an advancing crack, building up the stress within the crack. When this reaches a threshhold level, the total strain energy, including residual and applied stresses, is suddenly released by propagation of the crack. Then, additional corrosive material is sucked in, and the process is repeated.

Both men emphasize that their work is preliminary—but it does look as though answers, and preventive measures, are on the way. —ARG

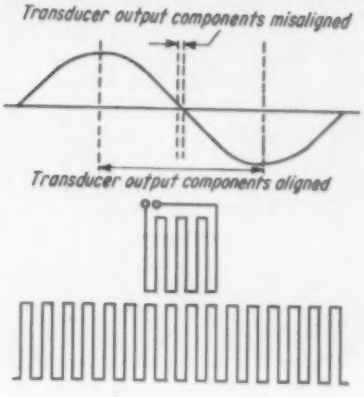
Analog and Digital Techniques Control Machine Member

MONTREAL, CANADA—A numerical machine tool control that represents a unique combination of analog and digital techniques has been developed by Sperry Gyroscope Company of Canada, Ltd. System incorporates highly accurate linear transducers, a tape reader that does not need a shift register or memory store, and a hydraulic valve that permits positioning accuracy at high travel speed.

The tape reader operates pneumatically, reading blocks of information instantaneously and obviating the need for a complex and costly shift register which would normally store information registered by sequential line-by-line readers. A block of information consists of 2 in. of tape and contains all command details pertaining to one hole position, plus any other auxiliary functions.

The transducers consist of slabs of a glass mica compound with a coefficient of expansion closely approximating that of steel. The slabs have plated on them a series of fine lines in the shape of an elongated hairpin coil.

Two major components form the transducer: a stator, made up of sufficient sections aligned end to end, to cover the travel length of the controlled axis. And a slider, similar to a stator section, plated in a series of 25 separate coils, each coil about 0.25 in. The slider is rigidly linked to the moving machine member and rides above the stator. A clearance of a few thousandths separates the stator and slider, hence no mechanical wear is introduced.



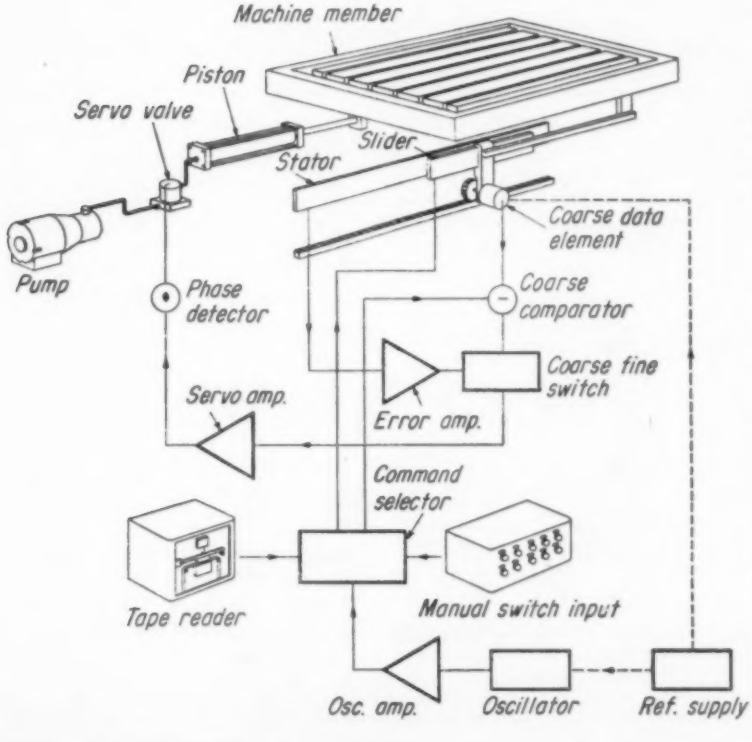
Low frequency ac excitation of any one coil on the slider will induce an approximately sinusoidal signal in the stator coil. Signal will be at full amplitude when the turns in the energized slider coil are exactly aligned with the stator coil, and the signal will fall off to a null when the two coils are misaligned, above. By phase shifting, the 25 separate slider coils give 50 null positions.

The Sperry control system can operate satisfactorily with any conventional machine drive such as ac, dc or hydraulic motors. However, the development of the Sperry electro-hydraulic servo valve is ideally suited for use with hydraulic pistons in industrial applications.

The valve features high immunity to dirt in the hydraulic system and requires no destructive dither impulse for smooth and instantaneous operation. Essentially, it consists of a body containing four ports—two to each side of the piston—a spool and a torque motor. Use of four ports balances the fluid flow in the valve and locks the table when it reaches its index position.

This control system, according to B. W. King, Managing Director of Sperry Gyroscope of Canada, Ltd, is now being manufactured for a number of US machine tool builders (see *PE—May 11, p 23*) and is being successfully applied to a wide variety of jig borers, turret drills, compound tables, and boring mills. ■

Combination of analog and digital techniques . . . controls table motion. Analog coarse data element brings machine member to about 0.050 in. of desired position. Electronic switching brings the digital fine measuring system into play to precisely position machine member to 0.001 in., with an accuracy of ± 0.0005 in. and a repeatability of ± 0.0001 in.



Design Self-quenching Control Rectifier

STAMFORD, CONN.—99%-efficient power control with over 100,000 hours life was recently predicted for new controlled rectifiers—"solid-state thyratrons"—by Arthur Gutterman, president of Fairfield Engineering. Advantages of a controlled rectifier over other controllable power switches is its very small size, longer life, and potentially lower cost. Table of comparative statistics, below, shows trend.

He also announced his recent development of a packaged self-quenching control unit for firing silicon-controlled rectifiers. The unit contains a half-gain, half-wave transistor preamplifier driving a reset magnetic amplifier.

Called Magnetic Rectifier Control Model R77P2, it consists of two sections: the first is a full-wave, push-pull MRC which will drive 2 sets of twin controlled rectifiers, and deliver either phase-reversible ac or polarity reversible, full-wave rectified dc-controlled power output. MRC can be operated from either a balanced or single-ended, polarity-reversible signal source.

According to Gutterman in his patent disclosure, controlled silicon rectifiers, or "gated diodes" are semiconductor devices that conduct no current up to a critical breakdown voltage, which is determined by current applied to a control element. In this respect it is somewhat like a thyratron tube except that on the latter breakdown voltage is determined by the voltage at the control element.

Future trends in power control, according to Gutterman, indicate that the saturable reactor, will remain for a long time. It's just a coil of wire around an iron core, and is about the simplest and most rugged of the power control devices. However, in those areas where the controlled rectifier will operate as well as the saturable reactor and a somewhat lower reliability can be tolerated, the rectifier may, if reasonably priced, be selected.

Because the controlled rectifier can be controlled directly it will probably replace the magnetic amplifier almost completely, Gutterman predicts. Magnetic amplifiers consist of a coil and a rectifier in series. The purpose of the coil is to control the rectifier. In many cases where the rectifier is less expensive than a magnetic amplifier of the same ratings, replacement has taken place.

"The thyratron and ignitron can be considered together," Gutterman explains, "and whether to use either of these or the controlled rectifier will be determined by the peak-to-average current ratio, or the voltage rating of the device in question."

Motor, welding, capacitive or battery-charging loads, which call for high peak currents, do not lend themselves well to the use of the controlled rectifier. On the other hand, resistive and inductive loads, with low peak currents lend very well to controlled rectifiers. ■

UK Presses Supersonic Airliner, Satellites

LONDON—The British government has asked aircraft companies here to submit detailed opinions on feasibility of a supersonic airliner. At the same time the government announced plans to launch fewer than ten satellites in a limited space program.

Aircraft companies have been asked to detail the extent of their interest, readiness to contribute to preparatory investigations, and type of organization they feel best suited for designing two supersonic aircraft. One of the proposed vehicles is a Mach 1.2 for 1500-mi range; the other a Mach 2 for non-stop North Atlantic service.

Whether Britain will undertake a

Device	Power level, kw (range)	Current, amp (range)	Max volts (range)	Filament and warmup time needed	Life (hr)	Oper Temp, C	Volts Drop	Effic, %	Gain	Values: Controlling means	Values: Size and wgt, per kw	Cost
Saturable reactor	1000's	1000's	500 to 1000	No	over 100,000	High	5–15	95	Low	DC current	High	Mod
Magnetic amplifier	100's	100's	200 to 600	No	10,000 to 100,000	−65 to +200	5–15	95	High	AC or DC current	High	High
Thyratron (tube)	10's	Up to 40	1500 to 10,000	Yes	10,000 to 50,000	−65 to +150	8–12	95	High	Phase-shift device	Mod	Mod
Ignitron	1000's	200 to 500	3000 to 20,000	No	10,000 to 20,000	about room temp	15	95	Low	Phase-shift device and thyratron	Mod	Mod
Controled rectifier (today)	10's	Up to 50	400	No	10,000 to 100,000	−65 to +125	½–1½	99	High	Phase-shift device	Very low	High
Controlled rectifier (future)	1000's	100's	1000 to 5000	No	Over 100,000	−65 to +200	½–1½	99	High	Phase-shift device	Very low	Very low

All approximate

full-scale space program with its own launching vehicles or will accept a US offer of transportation to orbit is still unknown. A team headed by Prof. H. S. W. Massey, Chairman, the Rocket Research Committee of the Royal Society, will travel to the US to discuss the matter.

According to a government source, the British are more concerned with obtaining an instrument package that will perform successfully than with a vehicle to get the package into orbit. He admitted this could mean a British program with satellites launched by the US from US soil.

However, a government scientist has stated that a modified version of Britain's Bluestreak for first stage and a modified Black Knight for second stage with a yet-to-be-developed third stage may be capable of putting a 1000-lb satellite into orbit.

The British space program at present is small scale. Cost has been put at "hundreds of thousands of pounds."

COMING EVENTS

MAY

25-28 . . . . American Society of Mechanical Engineers, Design Engineering Conference, Convention Hall, Philadelphia.

25-28 . . . . Clapp & Poliak, Inc., Design Engineering Show, Convention Hall, Philadelphia.

JUNE

4-5 . . . . Institute of Radio Engineers, 3rd National Production Techniques Conference, Villa Hotel, San Mateo, Calif.

8-11 . . . . American Rocket Society, Semi-annual Meeting, El Cortez Hotel, San Diego, Calif.

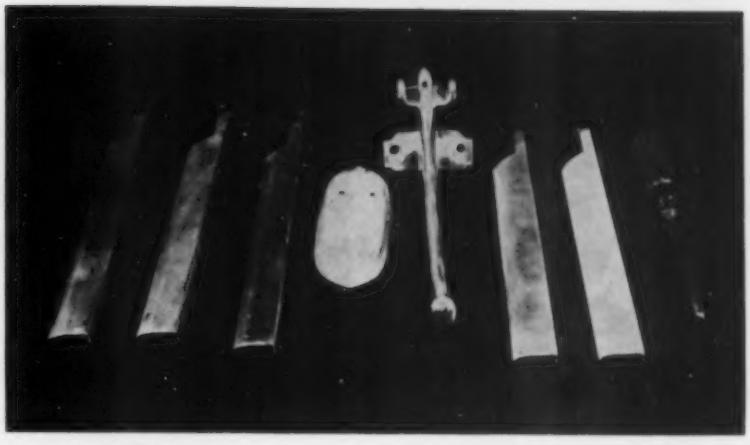
14-18 . . . . American Society of Mechanical Engineers, Semi-Annual Meeting, Chase-Park Plaza, St. Louis, Mo.

14-19 . . . . Society of Automotive Engineers, Summer Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

17-19 . . . . National Society of Professional Engineers, Annual Meeting, Commodore Hotel, New York.

18-20 . . . . American Society of Mechanical Engineers, 22nd Applied Mechanics Div, National Conference, Rensselaer Polytechnic Institute, Troy, N. Y.

21-26 . . . . American Society for Testing Materials, 62nd Annual Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.



Nonporous films . . .
of aluminum have been vacuum deposited on these automotive parts to provide tightly adherent, ductile films with properly oriented crystal structures, according to representatives of National Research Corp. Parts shown here include mild steel automotive trim, mild steel stamping and aluminum die casting.

Vacuum Deposit Aluminum Film

CAMBRIDGE, MASS—Vacuum deposition of highly protective, thick (0.5 to 1.0 mil) aluminum films on steels have been developed by National Research Corp. Now tightly adherent, ductile, nonporous films with properly oriented crystal structures can be made for automotive, aircraft, appliance and marine hardware components.

National Research has already produced films which can be anodized to give abrasion-resistant coatings with even greater corrosion protection. Materials already vacuum metallized (see above) with aluminum include: high tensile steels, cold rolled steels, hot rolled steels, aluminum die castings, aluminum forgings, and titanium. Development of vacuum-deposited corrosion-resistant aluminum films on aluminum alloy castings and forgings, and magnesium is continuing.

Development of the thick aluminum films is of particular importance to aircraft manufacturers requiring high tensile steel parts for protection against corrosion. Up to now, electroplated cadmium has been the most widely used as protective coating. Other methods such as flame spraying, hot-dipping, vacuum coating are used to a lesser extent.

When coating is electroplated, hydrogen is introduced, and embrittlement results. Depositions of thick films preclude introduction of hydrogen. Military specifications require that cadmium is not to be used on parts which will be at a temperature in excess of 500F, or in contact with other parts which will reach this temperature. It was this relatively low temperature limitation and the specific corrosion limitations that promoted interest in aluminum coatings.

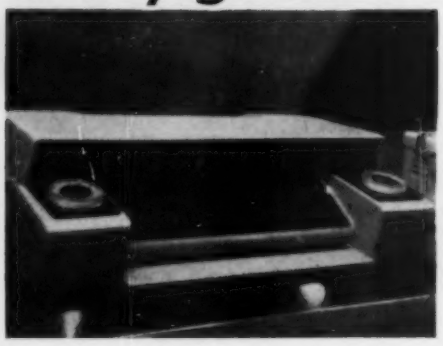
Satisfactory thick films of aluminum (up to 4 mil) and cadmium can now be vacuum deposited on high tensile steel parts. Corrosion resistance in salt spray is equivalent to that for solid cadmium or aluminum.

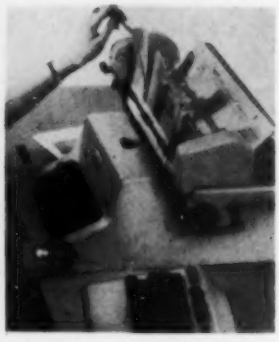
First public showing of thick-film aluminum-coated components will be at the June 14-19 meeting of American Electroplaters Society, and the Industrial Finishing Exposition, Detroit. ■

Fiber samples from Japan

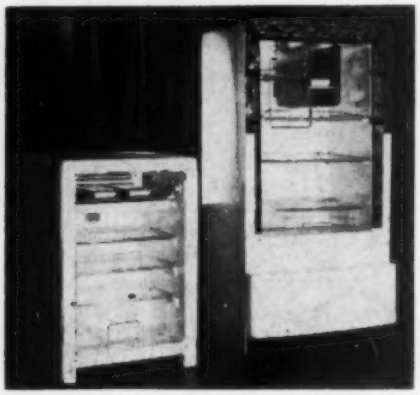
TOKYO—Samples of a new Japanese polyvinyl alcohol fiber on which Air Reduction Chemical Co holds the American license (*PE*—Aug 25 '58, p 8), are now available in developmental quantities. Airco is importing it to explore its market potential. The fiber is said to have good mechanical properties, and moisture and chemical resistance. It's expected to find industrial as well as consumer applications. ■

Merry-go-round of Fairs—

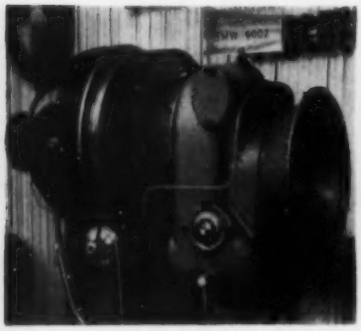


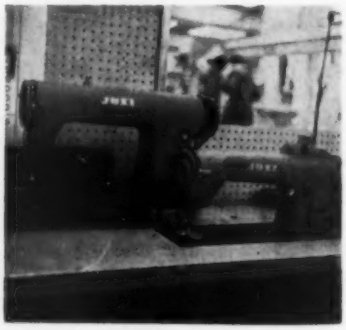


Competition for US in office equipment . . . is portended by foreign offerings. Typewriter (left) by Germany's Alpina Company is said to allow 14% increase in speed through broken space bar. Typist simultaneously depresses space bar with last letter of word; machine then automatically types letter and jumps space. The duplicating machine (center), manufactured by Marubosi Kiki Kogyo of Tokyo, is considered excellent design by Japanese authorities. German firm Siemag claims world's first fully electronic accounting machine (right). Textual data is fed to machine over typewriter keyboard; figures are fed through ten-digit keyboard.



Compactness and efficient . . . use of inside space are emphasized in foreign refrigerators. Frimatic of Paris (left) displayed its line at NY World Trade Fair. Suitable for US electric outlets, the unit comes in eight colors. The 43-in. model shown will retail for about $180. Unit by A. E. G. of Germany (center) shown at the Hannover Fair is insulated with foam plastic. Elimination of inner metal lining is said to reduce weight and provide more effective insulation The Fuji Denki model (right) was considered one of the best Japanese designs at the Tokyo Fair. Plastic top includes outlet for appliances as automatic electric rice cooker.





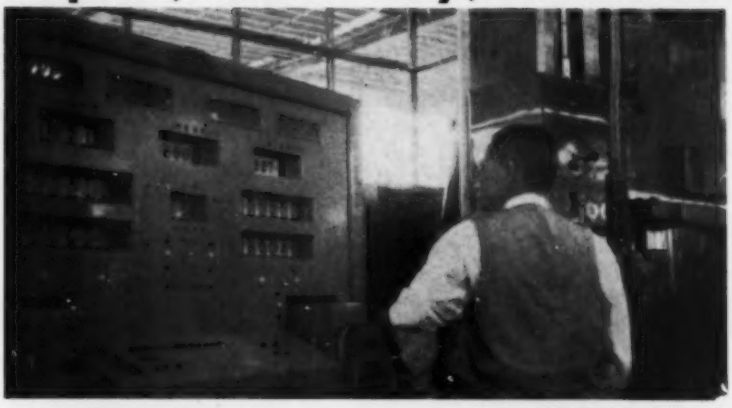
• Small gas turbine (left) by BMW is designed for eventual use in a vehicle. The 65-hp motor weighs 143-lb and consumes petrol, kerosine, diesel oil, light heating oil, or paraffin.

• "Who's pirating whom?" The Japanese ask when observing this US phone that duplicates a standard scarlet-colored pay coin model now in every small shop throughout the country.

• A Swiss micrometer, accurate to 1/10,000 in. includes six interchangeable anvils that rotate a full 360. This instrument, which comes in 0.1. and 0.4 in. size, was shown at the World Trade Fair, and is manufactured by Colyplan Co.

• Also from the World Trade Fair was the "Juki" industrial sewing machine (right)—another pacemaker in Japanese design. The machine works at speeds up to 4000 stitches a minute.

Japan, Germany, United States



Japanese achievements in advanced . . . machine tools were on view at Tokyo. Numerical controlled jig borer (top) was designed by the Government Mechanical Lab and manufactured by Mitsui Seiki. Control console includes electronic programmer, information panel for two tapes, and operation panel. The numerically controlled milling machine (bottom) by Hitachi is believed to borrow heavily from the West.

Small delivery trucks . . . emerge from both ends of Asia. The Japanese firm, Daihatsu, is offering a four wheel "Vesta" (top) which is said to have elicited inquiries for the US. This small company is reportedly bucking larger Japanese manufacturers by quality of its design. From Israel to the World Trade Fair comes the "Sabra" (bottom) by Autocars Co., Ltd of Haifa. The body is fiberglass on hardwood frame; the engine is of English manufacture. US price: about $1800.

The same week foreign countries showed the best of their products at three separate fairs. For this roundup, McGraw-Hill World News covered the overseas fairs to complete our picture story.

The annual whirl of spring trade fairs is in full swing. Arrayed on these pages is a sampling of industrial and household equipment that has recently been displayed on three continents.

The **German Industries Fair** in Hannover, which proclaims itself largest of the kind, drew 750 exhibitors from 26 countries this year—a considerable jump from last year's 606 exhibitors from 20 countries. The products displayed at Hannover ranged from housewares to heavy industrial and construction equipment.

Seasoned observers have commented that the products shown this year bear few departures from conventional designs, but are generally well conceived and neatly engineered. Observers also note that the narrow gap between US and German designs for office machinery is about closed. In certain instances, West German products may even have an edge over their American counterparts.

The **Japanese International Trade Fair** produced this year the most ambitious show in its five year history. The mart alternates annually between Tokyo, where it was this year, and Osaka, Japan's chief mercantile city. Despite rigorous rules barring propaganda exhibits (the Russians were out on these grounds) more than 4000 exhibitors participated. About ⅔ of the floor space was taken by machine tools and heavy machinery.

In Japanese equipment on display, there were signs that the nation's industry is moving away from absolute dependence on foreign design through licensing or piracy (*PE—July 21, 1958, p 20*). Pressure toward native design stems in part from Japanese officials who have been severely embarrassed time and again in their dealings with foreign countries because of design piracy. And these officials want to wean industry from dependence on foreign licenses to conserve foreign exchange. In part, too, Japan's scien-

tific community is anxious to pursue its own industrial research. But in the view of one Japanese design expert, independence has not gone far enough. Observing home grown machine tools and heavy machinery, he comment: Most of these are only copies of Western designs—and most of them are worse than the original."

US FAIR

The Third annual **World Trade Fair** in New York lured 3000 exhibitors from 63 nations. Though primarily a bazaar for display of handicrafts, food and home furnishings, the show remains the only opportunity for US engineers to observe the latest overseas OEM developments on this continent.

Displays included such household appliances as refrigerators and stoves, whose designs borrow the best from the US and eliminated some of our gaudier details. Exhibitors of such equipment have set themselves the hard task of breaking into the American market. ■

Urges Commercializing Space Technology

NEW YORK—The best defense for the United States is a sound economy. And a sound economy depends largely on commercial application of defense technology.

These views were addressed to the Association for Corporate Growth and Diversification here by General James Gavin, formerly Chief Research and Development for the US Army and now Executive V-P at Arthur D. Little, Inc.

His experience with federal budgets has taught him, Gavin said, that defense must be geared to what the economy can bear. If the economy is to expand in the future, industry must commercially apply space technology.

Several years ago, Gavin said, he and a scientist who was working on a nuclear weapons project discussed potential applications of nuclear energy. Both failed to foresee broad uses. But now, Gavin said, every industry has been influenced by nuclear technology.

He recently discussed applications of space technology with the same scientist. They agreed that rocket cargo carriers will be feasible eventually. But more important they felt that the space age is fostering research into the extremes of temperature that will be of much larger commercial significance.

The Soviets, Gavin noted, have used a turbo-jet powered drill for boring deep into the earth. This drill builds temperatures up to 3000 F for melting rock. With tools of such capability, resources deep within the earth and under the sea may yield to commercial exploitation. Further, cryogenics presently promises a six-fold improvement in radar, and similar advances in computers. Space research is also yielding a host of materials with wide commercial potentials.

NEED GOVERNMENT BACKING

Defense money, Gavin added, is supporting the forefront of knowledge and will continue to do so for better or worse. No company alone can afford the broad basic studies that are essential to today's technology. And no company can forego defense contracts if it is to remain in touch with technical advance.

In conclusion, Gavin named secrecy as a serious barrier to technical progress. Companies keep vital information from one another; the government refuses information to potential contractors because they cannot demonstrate "the need to know"; and the US refuses information to its allies, forcing them to duplicate work already done here and in the USSR. ■

Probe Outer Space Environment

PALO ALTO, CAILF—Two hundred top scientists at the Air Force-Lockheed sponsored symposium are exchanging information on current programs to investigate effects of the hostile environment of outer space on the protective shell of vehicles. Members of the group revealed new findings on the nature and composition of interplanetary material, on lubrication and greases for space flight, and glass for strain gage components to give new accurate measurements.

Radar measurements have told us a lot about the size and distribution of the dust in interplanetary space, said Professor David Beard of the Univ of Calif; but practically nothing is known about the actual composition of the material. A project now underway calls for a probe that will bring back samples of space dust in mylar envelopes for analysis.

Scientists would then be able to duplicate, said Beard, actual space flight conditions in laboratories to learn just what these particles will do when they impact. To maintain a liveable temperature in a space vehicle and to protect the occupants against radiation, designers must know whether particles will bounce off, adhere, erode, or penetrate.

LUBRICATION WAY UP

The problems of lubricating equipment under environmental extremes has necessitated pure research, according to Dr. Bruce Daniel, physicist from Mid West Research Institute. Graphite—once thought of as an ideal lubricant—is unsatisfactory in high vacuum because it loses lubricity when it loses water content. Sulphides of molybdenum and tungsten work well but cannot be readily bonded to surfaces for operation above 1000 F. This is a field, said Daniel, where the Russians have been expending a lot of effort lately. But fortunately, this is also a field in which there is not much secrecy. Under investigation, at present, are various special glasses and oxides of lead.

According to Joseph C. Richmond, the National Bureau of Standards is working on strain gages that will be able to measure the strains that are created during the over ration of high temperature equipment such as turbines of jet engines. There are three problem areas here. First, to find or develop a wire whose resistance is stable at high temperature; second, a nonoxidizing coating for the wire; and last, a suitable cement—one with a high electrical resistance, good adhesion, and the proper expansion-contraction characteristics. The bureau, said Richmond, has been working with simple glasses to which are added ingredients such as oxides of sodium, potassium, caesium. Basic information is being derived regarding the electrical conductivity of glasses at high temperature so that more information about how to use glass as a component of a strain gage as well as a material for other jobs will be gathered. ■

CIRCLE 116 READER SERVICE CARD→

Nickel-Coated THOMAS STRIP Cuts Aladdin's Metal Costs 56%

Aladdin had his fabled magic lamp.

But in real life, Aladdin Manufacturing Company uses nickel-coated Thomas Strip steel to work production magic in its Minneapolis, Minn., plant.

From copper to aluminum to slit steel sheets to plain strip and finally—to cold-rolled strip steel pre-coated with nickel by Thomas Strip Division of Pittsburgh Steel Company.

That's the route followed by Aladdin's Merrill B. (Ted) Wilcox in his five-year effort to find just the right metal for use in his company's line of handsome, useful Jon-E Hand Warmers.

Thomas Strip Division has grown into Aladdin's major supplier of nickel-coated strip because:

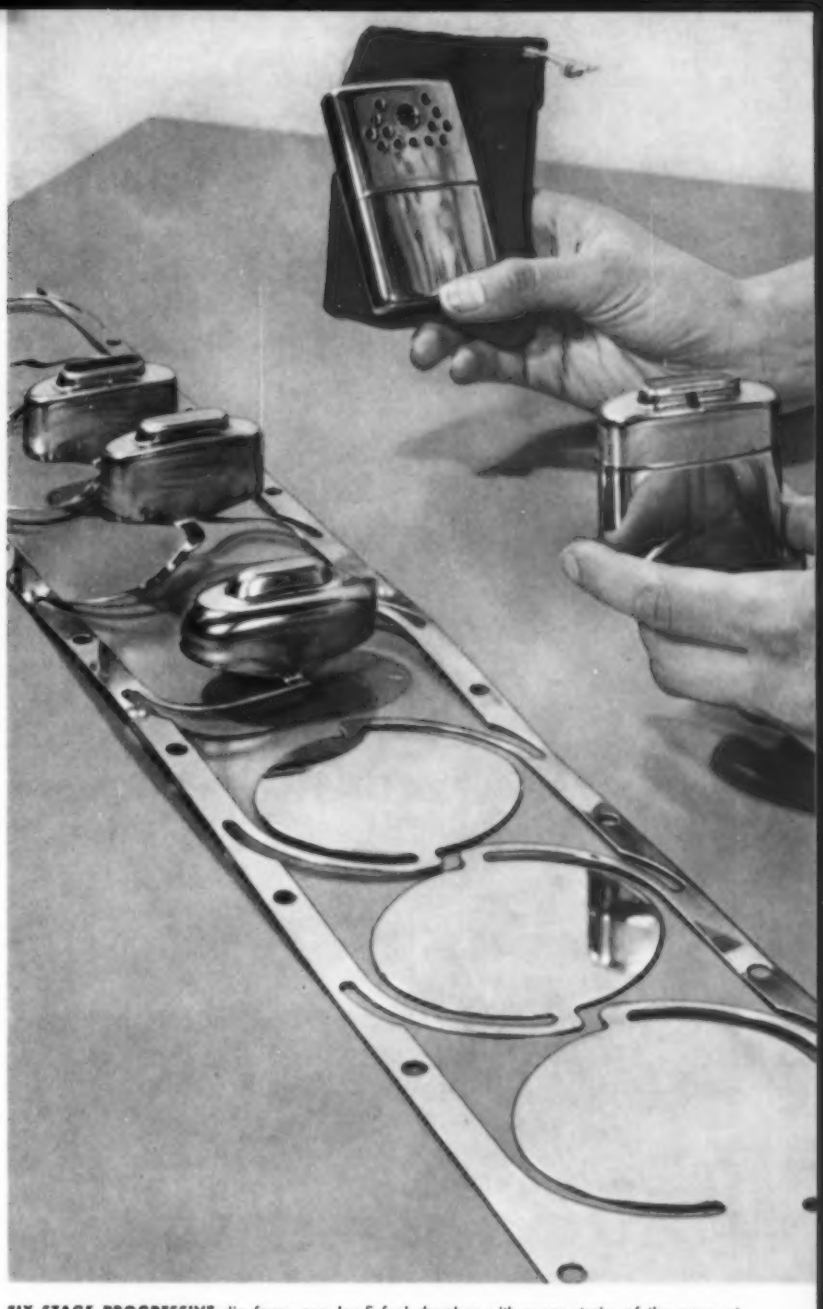
1. **Pre-coated nickel strip cut Aladdin's cost per pound of metal used from 50 cents for plain strip steel to 22 cents.**

2. **Use of nickel-coated strip enabled Aladdin to consolidate four separate production steps—each costing a cent—into a single step.**

3. **Pre-coated nickel cut scrap losses from a high of 20% (with slit sheets) to less than 1%.**

4. **Electrolytic coatings of nickel are more uniform, assuring the necessary snug fit of all Jon-E's components. And the only finishing Aladdin needs on nickel-coated strip is a quick ball-burnishing.**

All the production and design advantages of Thomas Strip are available to you. It is sold plain or electrolytically coated with copper, brass, nickel, chrome or zinc. Thomas also sells a full line of lacquered products. Call the nearest district sales office listed here. Do it today.



SIX-STAGE PROGRESSIVE die forms one Jon-E fuel chamber with every stroke of the press at Aladdin Manufacturing Company. This imposes severe demands on drawability of the 4½-inch nickel-coated steel strip supplied by Thomas Strip Division, Pittsburgh Steel Company. Aladdin credits Thomas Strip with 56% savings in metal costs, as well as sharply reduced scrap loss.

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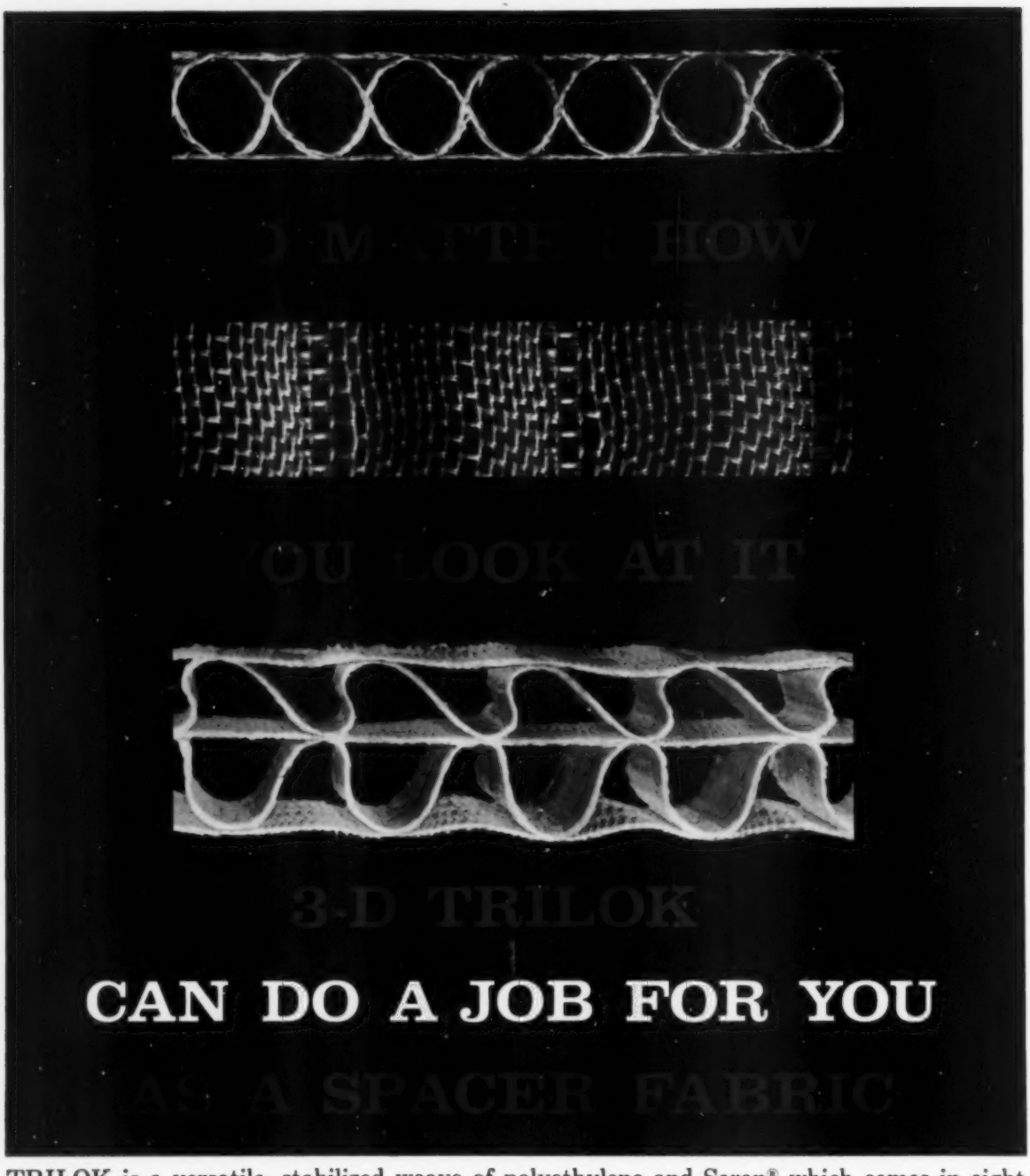

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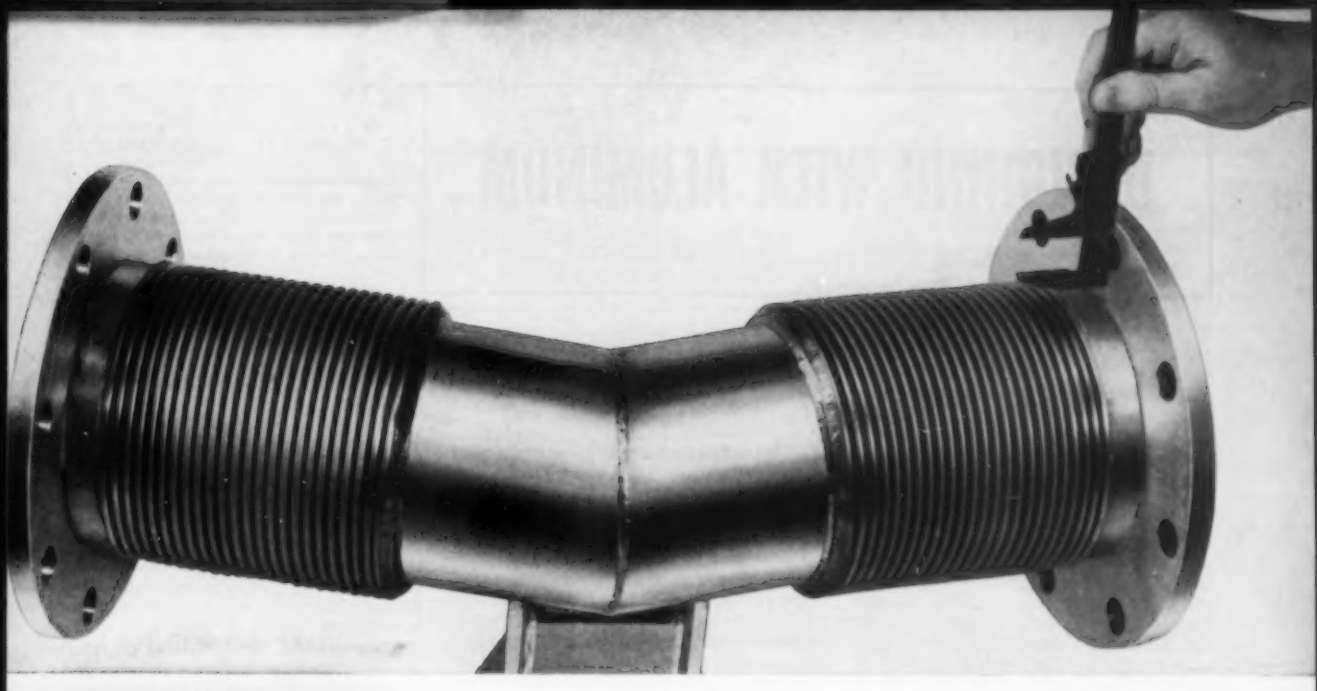
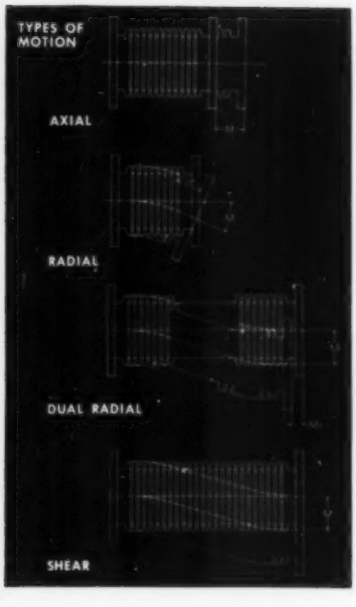


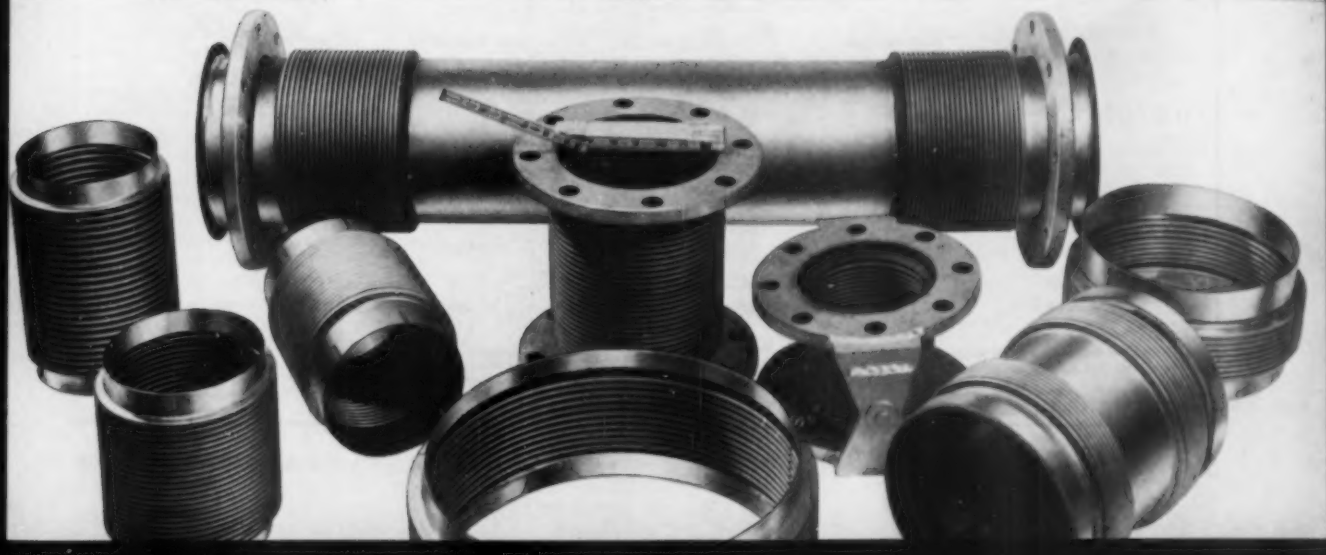


Expansion-joint tubing for big, tough jobs

New AX Tubing by Anaconda is available in Bronze, Stainless Steel, and other metals and alloys—from 4½" I.D. to 14" I.D.—to handle axial and lateral movement.

Need to compensate for contraction of piping suddenly cooled to minus 300°F by a large volume of liquefied gas? Want a bulkhead seal that "gives" with hull movement? Do you need a special assembly like that above, which handles an offset and a combination of lateral and axial movement? Wherever you need large diameter tubing to take care of movement shown in drawing at left, or simple offset, write: Anaconda Metal Hose Division, The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 59128

ANACONDA® METAL HOSE



DESIGNING WITH ALUMINUM

NO. 30

This is one of a series of information sheets that discuss the properties of aluminum and its alloys with relation to design. Extra or missing copies of the series supplied on request. Address: Advertising Dept., Kaiser Aluminum & Chemical Sales, Inc., 919 N. Michigan Ave., Chicago 11, Illinois.

ALUMINUM IN LOW TEMPERATURE APPLICATIONS

THE STRUCTURAL QUALITIES of aluminum and its alloys are actually improved at ultra-low levels of temperature, such as are encountered in the manufacture and handling of liquid gases. Tensile and yield strengths rise markedly, and percentage of elongation increases. As the lowest-cost metal capable of performing satisfactorily at temperatures below –150°F., aluminum is thus valuable to the rapidly expanding field of cryogenic applications.

Aluminum alloys also are unique among commercial metals in their combination of high strength-weight ratio, corrosion resistance, formability, weldability, reflectivity, and conductivity of heat and electrical energy. Also important for purposes of handling volatile liquids, aluminum is non-sparking, nonmagnetic and non-toxic.

The requirements of commercial gas applications are filled chiefly by four industrial gases (see Figure 1). Oxygen, nitrogen, argon and helium—in that order of volume—comprise much the greater portion of commercial gas manufacture. Oxygen, nitrogen and argon are among the gases that are produced by liquefying air at –320°F. to effect a separation of each gas at its individual boiling point as a liquid. Equipment for this production can use, and has used, large quantities of aluminum alloy sheet, plate, extrusions, tubing and pipe.

These gas products, along with natural gas (mostly methane) are reduced by cooling and liquefaction to volumes only about 1/600 to 1/800 of their gaseous volume. *And because consumption by industry in both old and new applications currently amounts to hundreds of millions of cubic feet annually,* this reduction in handling bulk is of immense economic importance.

One of the latest military missiles, for example, consumes 420 cubic feet of liquid oxygen . . . 336 thousand cubic feet as gas . . . in a 90-second firing period. These liquefied gases may be stored and moved in aluminum alloy double-shelled insulated tanks, thus taking advantage of their extreme concentration in the low-temperature liquid state.

Double-shelled mobile liquid-oxygen tank, produced with Kaiser Aluminum alloy 5086. Used in fueling missiles, this tank is being loaded for transport by air.

FIGURE 1

SOME PROPERTIES OF COMMERCIAL GASES

	BOILING POINT OF LIQUID GAS (Fahrenheit)	LIQUID DENSITY AT BOILING POINT (Lbs./cu.ft.)	GAS DENSITY * (Lbs./cu.ft.)	APPROX. VOLUME INCREASE, LIQUID TO GAS *
OXYGEN	–297	71.2	0.089	799
NITROGEN	–321	50.4	0.078	650
ARGON	–302	88.02	0.1114	770
HELIUM	–452	7.82	0.0111	700
NATURAL GAS (Chiefly Methane)	–265	25.9	0.0447	580

* Gas at normal temperature and pressure.

FIGURE 2

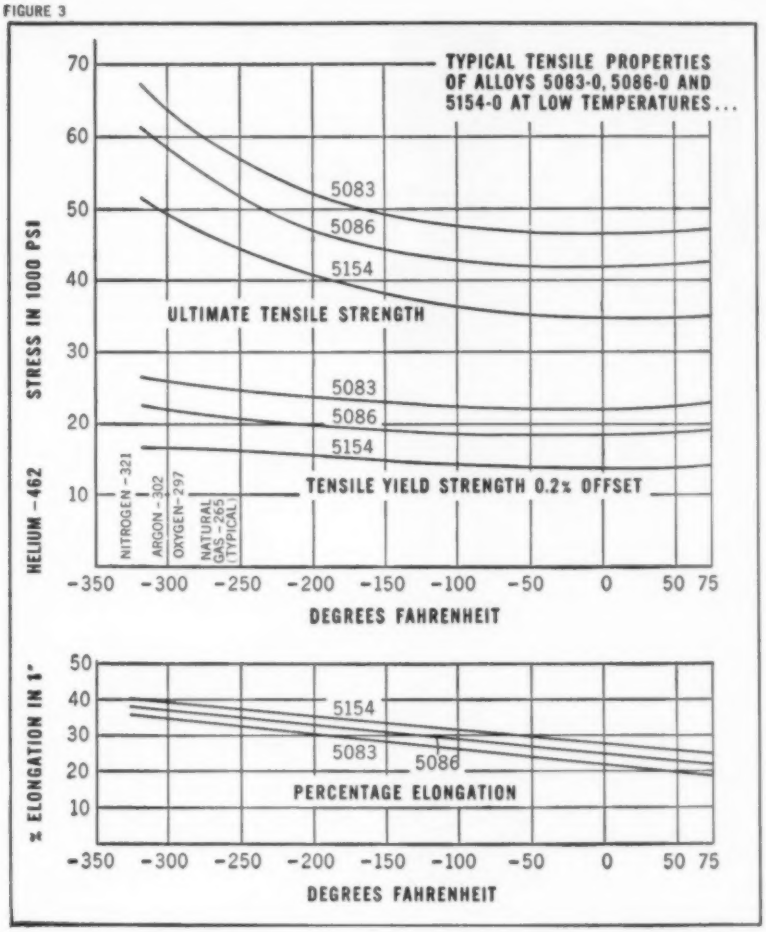
TYPICAL TENSILE PROPERTIES OF SOME ANNEALED ALUMINUM ALLOYS APPROVED BY ASME FOR UNFIRED PRESSURE VESSELS

ALLOY DESIGNATION AA	ALLOY DESIGNATION ASTM	ASME SECTION OR CASE NO.	TENSILE STRENGTH (psi) Ultimate	TENSILE STRENGTH (psi) Yield	ASME ALLOWABLE DESIGN STRESS * VALUES (psi)	MINIMUM REQ'D WELDED TENSILE STRENGTH (psi)	PERCENT ** ELONGATION
1100	990A	8	13,000	5,000	2,350	11,000	35
3003	M1A	8	16,000	6,000	3,150	14,000	30
3004	MG11A	8	26,000	10,000	5,650	23,000	20
5050	G1A	8	21,000	8,000	4,000	18,000	24
5052	GR20A	8	28,000	13,000	6,250	25,000	25
5154	GR40A	1174	35,000	15,000	7,350	30,000	27
5086	GM40A	1222	38,000	17,000	8,700	35,000	22
5083	GM41A	1247	42,000	21,000	10,000	40,000	22

* For metal temperature not exceeding 150°F.
** In 2 inch flat 1/16" gauge specimen at 75°F.

Nominal chemical compositions:
5154—Magnesium 3.5%, Manganese 0.05%, Chromium 0.25%
5086—Magnesium 4.0%, Manganese 0.45%, Chromium 0.15%
5083—Magnesium 4.45%, Manganese 0.75%, Chromium 0.15%

FIGURE 3



Several weldable aluminum alloys have been approved by the American Society of Mechanical Engineers as safe and suitable for construction of unfired pressure vessels such as are used in the handling of liquid gases.

Figure 2 tabulates typical tensile properties and the design stresses permitted by the ASME Code for some of these alloys, including high strength aluminum-magnesium compositions. All values shown are for metals in the annealed state. Kaiser Aluminum alloys 5083 and 5086 are the strongest ASME-approved aluminum-magnesium-manganese alloys that can be fabricated into these welded vessels by all normal methods, without need for stress-relieving or annealing. Both of these Kaiser alloys 5086 and 5083, when welded with 5183 filler, also meet the stringent "2T" bend test requirements for welds established by ASME for most other materials in these unfired pressure vessel applications.

The allowable design stress values shown are specified by ASME as acceptable for vessels and appurtenances from 150°F. down to –325°F. These permissible values are roughly two-thirds of the minimum guaranteed yield strength of the alloy at room temperature. Since the ultimate tensile and yield strengths of aluminum alloys increase as temperatures drop, the margin of safety rises still further at liquid gas temperature levels.

The low temperature behavior of alloys 5154, 5086 and 5083 is exemplified approximately in Figure 3. Ultimate strengths increase by about 50% from room temperature to –320°F. Yield strengths rise by about 18%. Thus, at the –320°F. level, the yield strengths of these three high-strength alloys approximate 2¼ times the stresses allowed for pressure vessel design by the ASME Code.

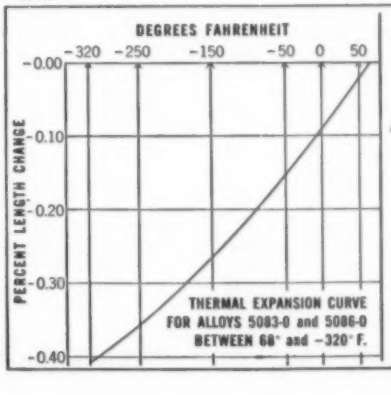
Through the same temperature range, percentage elongation properties have been shown by test to increase 60% or more, reaching the magnitude of 40% elongation at –320°F.

This added strength and ductility contribute much to structural dependability against both mechanical shock and large temperature differentials in different portions of the same aluminum part or system.

The thermal contractions encountered in ultra-low temperature equipment are larger than those to be accommodated in ordinary design applications. For example, an aluminum member 25 feet long contracts by about 1¼-inch through the range from 68° to –325°F. Figure 4 shows these thermal expansion characteristics, as typified by aluminum alloys 5086 and 5083.

The low elastic modulus of aluminum also contributes to its suitability for low-temperature equipment by mitigating the adverse effects of thermal contraction. Thermal deformations cause much smaller increases or decreases of stress in aluminum parts than in equivalent stainless steel parts. The representative #304 stainless steel listed in Table 4 will contract only about 70% as much as the high strength weldable aluminum alloys, for any given drop in temperature. However, the aluminum alloys have an elastic modulus of about 10,300,000 psi, roughly one-third that of the steel. Because of this difference in elastic moduli, the stress changes resulting from thermal deformation through any given temperature change

FIGURE 4



THERMAL EXPANSION COEFFICIENTS OF ALUMINUM ALLOYS AT LOW TEMPERATURES

Average Coefficients of Thermal Expansion (x 10^{-6} per degree F.)

ALUMINUM ALLOYS	68° to –200° F.	68° to –320° F.
1099	11.8	10.5
3003	11.2	10.0
5083	11.6	10.4
5086	11.6	10.4
6061	11.3	10.2
#304 Steel (Stainless)	7.7	7.4

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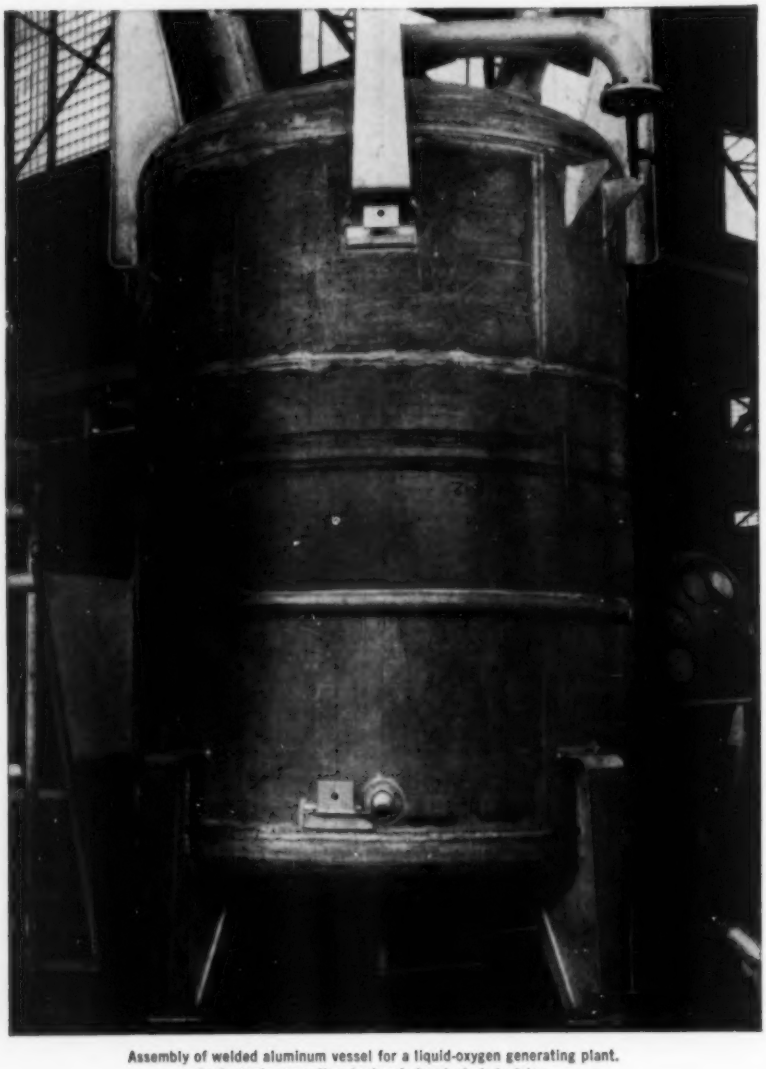


Assembly of welded aluminum vessel for a liquid-oxygen generating plant. Such plants serve the steel and chemicals industries.

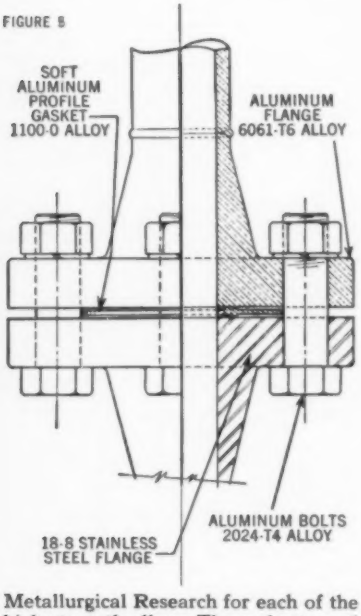
will be lower in the aluminum than in the steel.

One example of the advantages offered by this capacity for large elastic thermal deformations is the ability of aluminum alloy flanged joints, using 2024-T4 aluminum bolts, to maintain joint tightness under cyclical temperature conditions between 250°F. and −320°F. A bolt-loosening effect naturally occurs during the initial contraction of the pipe bore as it is cooled to liquid-gas temperatures, while the outer flange and the bolts remain relatively uncontracted at ambient levels. This tends to reduce gasket seating pressures. However, the loss of stress in aluminum bolts and flanges during thermal contraction of the pipe is much less than that occurring in equivalent steel parts. This ability to maintain stress during thermal deformations, along with the use of a soft aluminum profile gasket next to the bore, maintains adequate sealing while the flanges and bolts also cool. Since it often is desirable to bolt an aluminum flanged line to a stainless steel flanged line, for heat-dam purposes, this elastic property dictates that aluminum alloy 2024-T4 bolts should be used.

Metallurgical Research Data Now Available

Since most liquid-gas containers require a high vacuum between outer and inner shell to achieve the best possible insulating conditions, external pressure design charts have been developed by the Kaiser Aluminum Department of Metallurgical Research for each of the high strength alloys. These charts, and other information on aluminum use in low temperature applications, are available to interested manufacturers.

FIGURE 5


SOFT ALUMINUM PROFILE GASKET 1100-0 ALLOY
ALUMINUM FLANGE 6061-T6 ALLOY
18-8 STAINLESS STEEL FLANGE
ALUMINUM BOLTS 2024-T4 ALLOY

For immediate attention to your request for these charts and other technical information—or for engineering assistance in your own applications—contact the Kaiser Aluminum sales office listed in your telephone directory.

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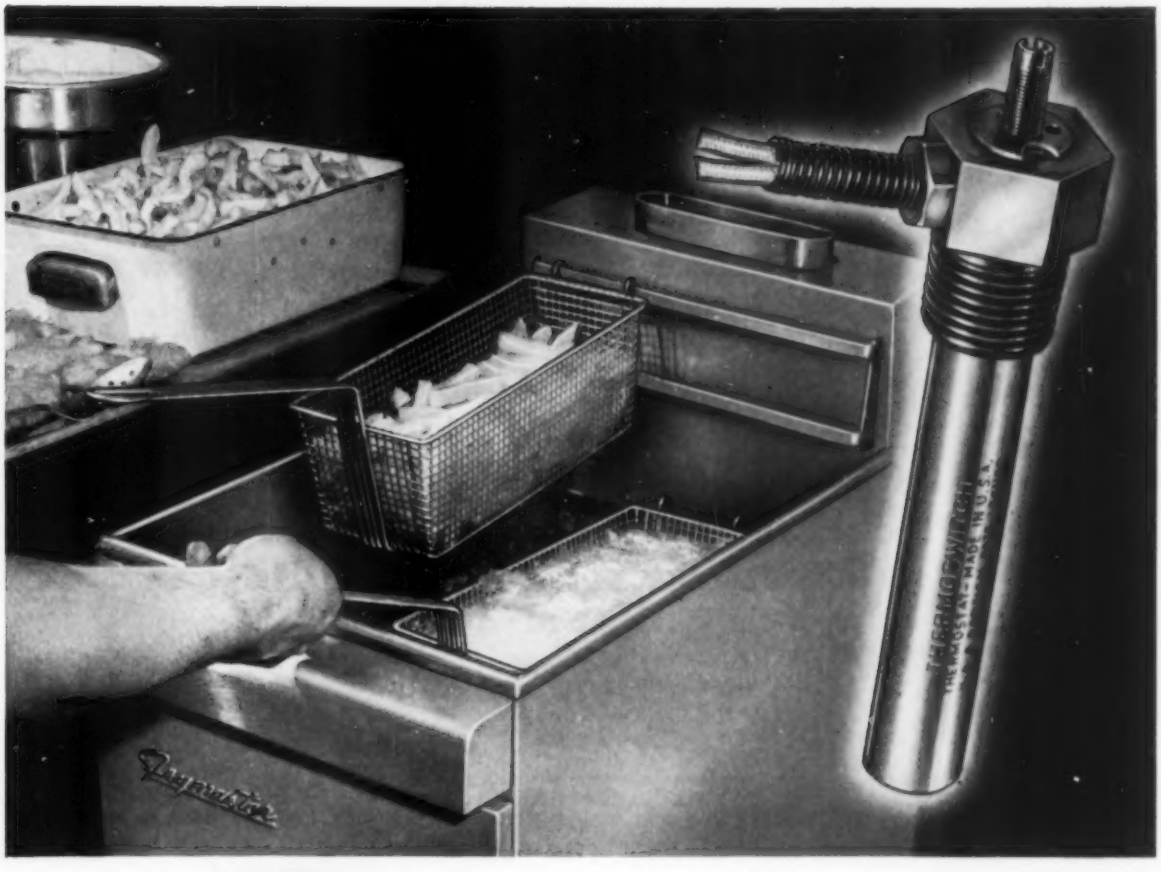
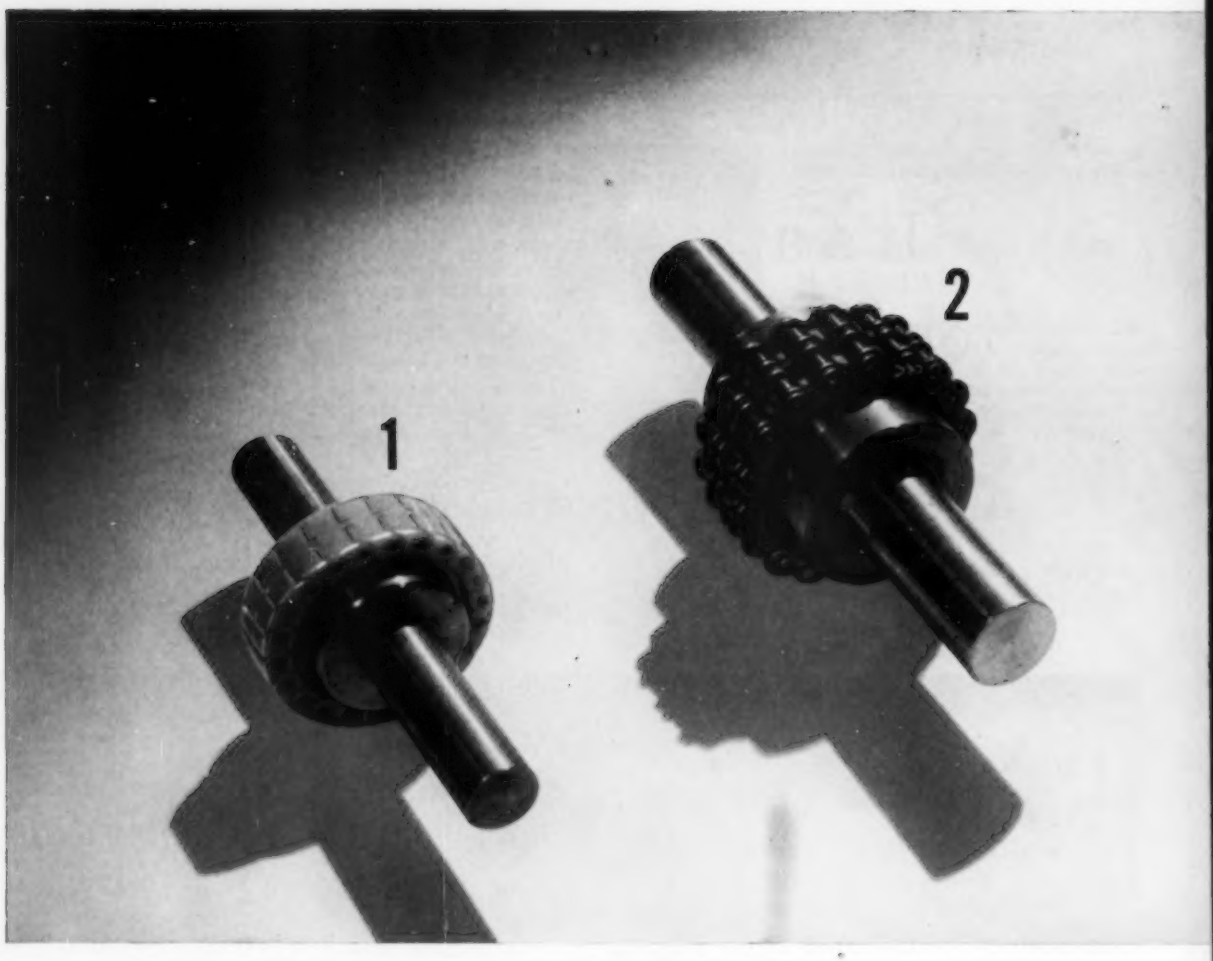


Fenwal CONTROLS TEMPERATURE . . . PRECISELY



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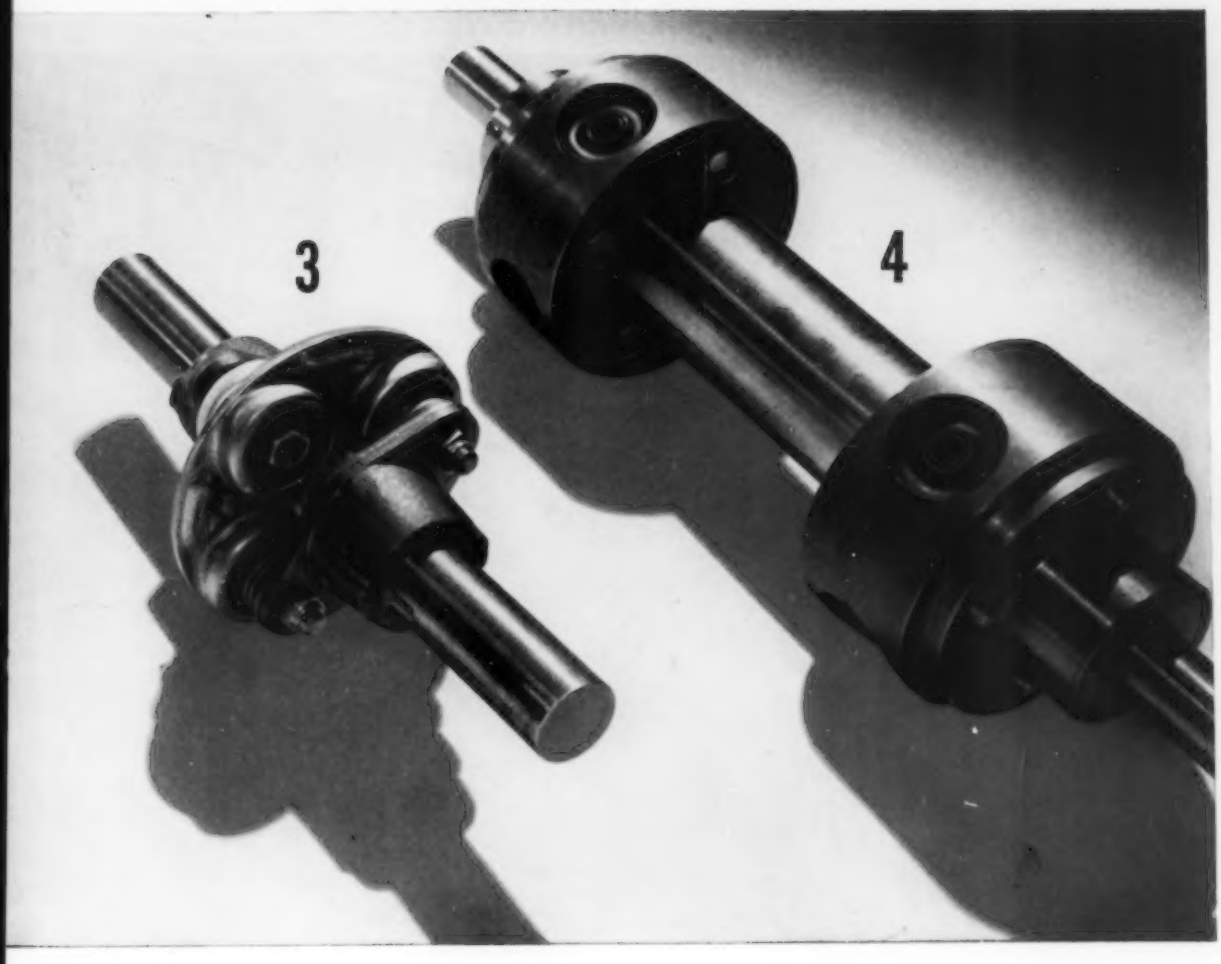

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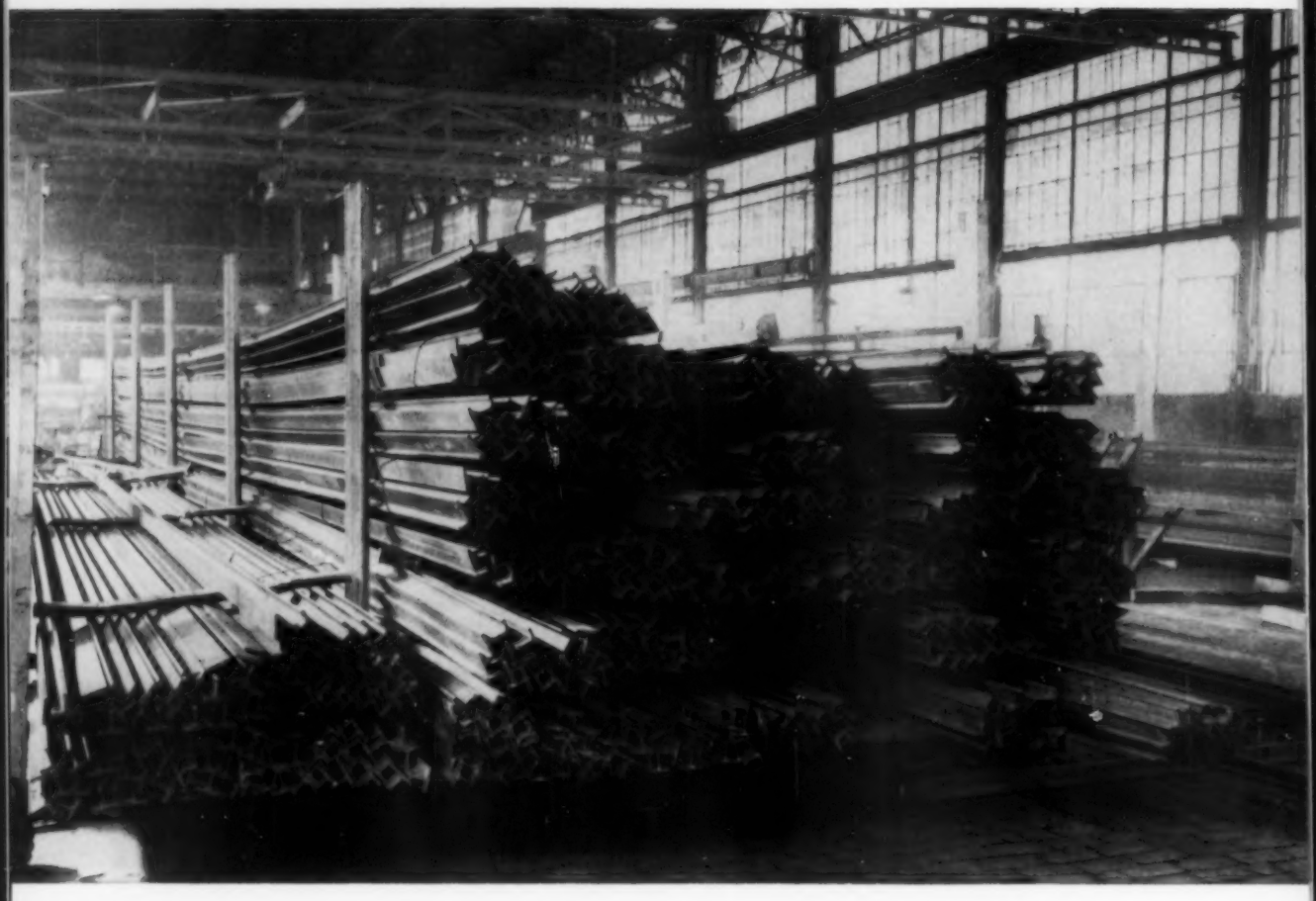

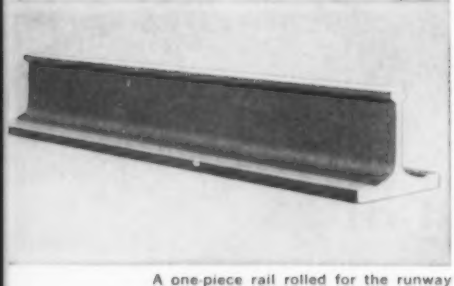

A one-piece rail rolled for the runway of Cleveland Tramrail Systems. This track has flat raised treads designed to minimize peening. No machining is required on this USS Special Section.

Tramrail—non-peening, no machining made from USS Special Sections

This supply of rails for Cleveland Tramrail Systems represents a cost saving running into many thousands of dollars. They are USS Special Sections rolled to exact size and cut to proper length. If the rails had to be machined from bars of high-carbon or alloy steel, the cost would be prohibitive and scrap losses tremendous.

The steel is furnished in a high carbon grade which serves to minimize track wear caused by wheel peening on the track tread. The manufacturer says that in 30 years no other overhead track has been offered that surpasses this one for durability.

It's seldom that better products can be produced at substantially lower costs but that's what happens when you use rolled USS Special Sections. Rolled to the predominating cross section needed, it is a custom-tailored part, designed and rolled so that there is little or no finishing required to meet final specifications.

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PERSPECTIVES

in design and development . . .

The Company Takes a Hand

In an article appearing in Product Engineering about a year ago, E Lawrence Chandler, assistant secretary of ASCE and treasurer of EJC wrote, ". . . engineers who are members of the national societies . . . are more professionally minded and competent than those who are either not qualified or are not sufficiently interested to be members."

That's about as strong a challenge as we've seen in print. But engineers are not "joiners." We would estimate that only one engineer in five belongs to a society. (EJC guesses 350,000 memberships for a total of 825,000 engineers. But this includes considerable duplication.)

Proponents of more professional prestige for engineers have been complaining about the situation for years, to no avail. Prestige is evidently not enough. But company interest can be relied on as a much more effective persuader.

"A company's progress is measured by its ability to grow," says Louis J Frangipane, supervisor of engineering liaison, Kearfott Co Inc, "and growth is measured by progress in individuals as much as in increased square footage or number of employes. Engineers grow by gaining in knowledge and by developing themselves professionally. Professional societies are set up specifically to meet these objectives. They are dedicated to the advancement of technical progress and the exchange of information. And so the company has a measurable stake in the participation of its engineers in society activities."

To find out where it stood, Kearfott took inventory of its men to learn how well and how actively the company was represented. The survey showed it was well represented (224 memberships for 330 engineers). But it also gave enough data for a plan of financial encouragement as well as a file, by society, for memberships held. This file is now used to locate copies of proceedings, society journals, and as a source of references for new applicants to societies.

Perhaps you would be interested in the recommended financial-assistance plan:

"Any financial assistance would result in a substantial increase in memberships; however, we wanted to encourage and assist *active participants*, not passive members. Free memberships would encourage the passive variety. For this reason, only moderate financial assistance is recommended for membership dues in the first year. Specifically we recommend the company subsidize 1/3 of the dues the first year, 2/3 the second year and possibly full payment the third year. This arrangement should encourage sustained memberships.

"Participation would be more effectively encouraged by permitting the engineers to attend their societies' annual conventions. In this way an engineer is more inclined to take part in society activities, committees, study groups, etc. We recommend that engineers desiring to attend these conventions make application through their supervisor to a professional-society trip-authorization board which would consist of the chief engineer, the assistant chief engineer, laboratory head and a representative from engineering administration. The application would indicate special reasons for wishing to attend. This would serve as an incentive to join committees, write papers, etc. . ."

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Product Engineering

HORIZONS

May 25, 1959

Design is not a SPECTATOR Sport

Sports promoters decry the decline in audiences—the fans stay home. Tool and hobby stores are booming with the do-it-yourself movement. More Americans are traveling, fishing, golfing—while professional ball teams change towns to stay in business—the so-called "spectator sports" fail.

Circuses have trouble—the entertainment of the people since the time of Rome. Nobody turns out to watch parades or other public affairs.

In Moscow, they observe the anniversary of the October Revolution in November—which makes sense to a Russian. This is of only passing importance. The point is that *everybody* parades—there are no spectators. Herein lies a significant point. *Everybody parades!* What are parades for? Even in New York, come St. Patrick's Day, there's a big parade, thousands marching for hours. Only a few marchers ever saw the Emerald Isle, or can resurrect grandsires who did. But they parade.

Why? All these assorted happenings have the same cause. *We're tired of being spectators.* The nation that enjoyed the leisure to sit down and watch has found that sitting down loses its savor after a while. Sitting leads to callouses on the anterior as well as the posterior portions of the anatomy.

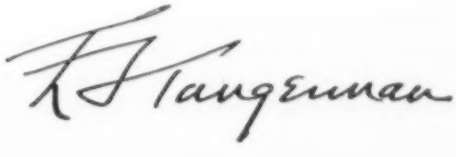
There are, of course, two ways to be involved with anything—as a participant and as a spectator. But only participation is rewarding in the long run. At the risk of being considered banal, we suggest that this is true of design: You can do the job mechanically from a handbook or by rote from "policy." You can—in effect—be a spectator. There'll be a product as a result, but it won't have all it should have. There must be at least a little of yourself in it if it is to live.

Many of today's products are designed against a price, or against a competitive item. They contain no idea, no intrinsic quality, no newness. They are merely copies, herd-bound, and provide no satisfaction either to the maker or the user. As our manufacturing organizations become bigger and mass-production mechanizes manufacture, the tendency is to do spectator design. That's uninteresting, pedestrian, dead—and the products show it.

Periodically, someone takes his life in his hand and designs something new and refreshing. It goes. Then the copyists duplicate it in cheaper materials for lower costs. And this is called progress—until the buyers revolt.

Thus we arrive at almost-worship of creativity and originality, which after all is a rather fundamental thing. Psychologists say we're all creative—except that in most cases the ability is never developed. Perhaps this is the solution to the problem—to permit creativity rather than to worship it, to let the creative mind go, trying something new rather than herding it into a brainstorming session in the desperate hunt for a gimmick, an angle.

The risk is, of course, greater, but so are the rewards.



when:
flange metals
don't match and
temperatures
fluctuate . . .
here's

HOW GASKETS BEHAVE

Sparked by more aluminum in auto engines, gasket design techniques are being overhauled to fight high-temperature loosening. Here's what latest research shows about the way typical gasket materials behave in aluminum-steel joints cycled to 300 F.

E M SMOLEY, *research physicist*
Research and Development Center, Armstrong Cork Co

Like any dissimilar-metal joint, a seal made by clamping a gasket between two flat-faced flanges—one aluminum, the other steel or cast iron—tends to loosen when temperature fluctuates. The reason: aluminum has a thermal expansion coefficient roughly twice that of steel or cast iron. This difference requires the gasket to perform two new functions: It must be stiff enough to resist plastic flow as the aluminum flange expands faster on heating—sometimes adding as much as 2 mils to normal gasket deflection; it must be elastic enough to retain bolt loading as the aluminum flange contracts faster on cooling.

Recent research shows gasket materials currently on the market will do both these jobs, some more efficiently than others. The following discussion shows how some of these materials react to thermo-mechanical effects in actual joints, and which types retain bolt loading best. Until research on gasket material behavior progresses a bit further, the exact amount of bolt loading a specific material will retain in a specific design must be determined by test on that design. As a materials comparison, however, the test results described here are valid for any joint design.

TORQUE-RETENTION CRITERION

When operating temperatures exceed 250 F and mechanical vibrations are present, retention of bolt loading can be just as important a gasket function as sealing the flange interfaces against fluids under pressure. Here, loss of bolt loading can result in leakage even though the seal was sound when the joint was initially tightened. Bolt torque—the torsional effort required to just ease the bolt into motion in the tightening direction—is used as a measure of bolt loading because it is easily determined with a torque-wrench. Torque loss, then, is a measure of loss of clamping force.

A formal relationship between torque losses and the sealing function has yet to be demonstrated. Even so, the above argument—stemming from field experience—is a logical one. Torque loss, then, is presumed to be an important factor working against maintenance of a good seal.

How does bolt torque vary under conditions of fluctuating temperature? A good example is the transmission housing assembly shown above. Here, an aluminum cover flange is clamped to a cast iron housing with steel cap screws threaded into tapped holes in the housing. A typical test requires starting with a leak-tight seal at room temperature, heating the assembly in an oven to a specified equilibrium temperature, holding for a given time, and finally cooling to room temperature.

By checking bolt torque at intervals throughout the cycle, a plot of bolt torque vs time can be made like that of Fig 1 for 300 F. Such a spectrum, though taken from a specific flanged assembly, is useful for comparing

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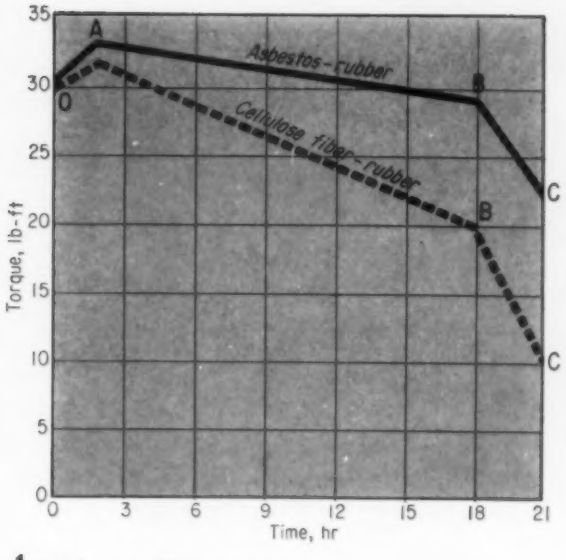
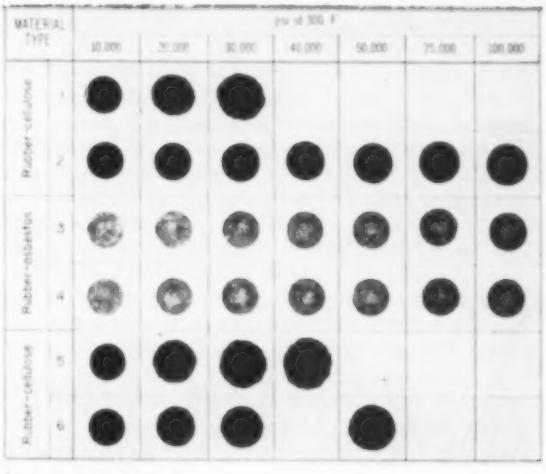


1 Bolt torque diagram . . .
shows effect of thermal cycling to 300 F on gasketed joint with one aluminum flange and one cast iron flange. Increase from O to A is due to aluminum expansion; A to B represents normal loss at oven temperature; B to C is loss due to aluminum contraction. Same test repeated for several materials sorts out gaskets that retain bolt loading best.

2 Gasket extrusion . . .
at bolt holes is common type of damage for gasket materials which cannot compensate for extra deformation caused by aluminum flange expanding faster than cast iron or steel flange.



3 Hot-extrusion test . . .
compares capacity of gasket materials to resist plastic flow as aluminum flange expands faster than cast iron or steel. Types (3) and (4), asbestos-rubber combinations, resist extrusion best; others are commercially available combinations of cellulose fibers and rubber.

materials with one another and for the insight it can give to the functions these materials must perform. An inspection of this diagram shows there are two basic functions, and that they require compromise in material selection since they are contradictory functions.

EXPANSION EFFECTS

First new function the gasket must perform is to translate the thermal expansion strains imposed by the more rapidly expanding aluminum flange into bolt torque increases. This is the way the gasket compensates for greater-than-normal deflection. On the torque spectrum diagram, this rise occurs from O to A, representing gasket loading over and above that achieved on initial tightening at room temperature.

When this torque rise fails to materialize, it usually means the gasket is extruding at the bolts, as in Fig 2. Such plastic flow is undesirable, since it leads to uneven bolt loading and hence possible leakage. A simple compression test at elevated temperature is a good way to judge a given material's resistance to flow in this part of the thermal cycle. The pressure at which perceptible enlargement of the test area occurs is the limiting pressure for that material. Fig 3 shows that combinations of asbestos fibers and rubbers will resist loads up to 100,000 psi—near the yield point of many metal flange components.

During the constant temperature part of the cycle, from A to B in Fig. 1, some torque loss takes place as the gasket softens. This is essentially a compression creep effect. The solid curve is for asbestos-rubber compositions, while the dashed curve represents the cellulose fiber-rubber blends of Fig 3. For either curve, the loss from A to B is that which normally occurs when both flanges are cast iron or steel. In effect, using one aluminum flange merely shifts the torque spectrum upward.

CONTRACTION EFFECTS

Second new functional requirement is that the gasket must keep torques from falling too much even though the aluminum flange contracts more rapidly than the steel one on cooling. This torque drop is shown from B to C,

TABLE I—TORQUE-LOSS TEST RESULTS

Calculated for materials in Fig 3 from torque-loss curves like those of Fig 1, and averaged over several tests. Gasket thickness = 1/64 in.; initial torque T_o = 30 lb-ft

Material Type	Hot Torque T_B, (lb-ft)	Torque Loss $(T_o-T_B)/T_o$, (%)	Cold Torque T_c, (lb-ft)	Torque Loss $(T_o-T_c)/T_o$, (%)	Torque Difference $(T_B-T_c)/T_B$, (%)
(3)	29	3	22	26	23
(5)	20	33	10	67	33
(2)	20	33	9	70	37
(1)	15	50	7	76	26
(8)	11	63	5	83	20

TABLE II—HOW GASKET THICKNESS AFFECTS HOT TORQUE LOSS

Material Type	Thickness, in.	% Loss, $(T_o-T_B)/T_o$
(3)	1/64	0
	1/32	13
(1)	1/64	13
	1/32	43

TABLE III—HOW CAP SCREW LENGTH AFFECTS HOT TORQUE LOSS

Material Type	% Loss, $(T_o-T_B)/T_o$	
	For 0.65 in.	For 1.63 in.
(3)	29	0
(1)	47	13

and is caused by the tendency of the aluminum flange to pull away from the gasket. The ideal gasket material would be resilient enough to compensate perfectly for this tendency, allowing no break in the curve at *B*. Such materials are not available; however, those represented by the solid curve are among the best in this regard.

How one gasket material compares with another is now fairly clear. Table I shows values taken from the torque loss curves of several of the materials compared in Fig 3. The torque differences in the last column indicate the gasket's ability to compensate for contraction effects. The smaller this figure is the better the gasket, with one exception: When the hot and cold torque losses (points *B* and *C* compared to *O*) are as high as for gaskets of type (1) and type (8) material, the last column no longer shows how well the gasket compensates for contraction. On this basis, type (3) material is best.

FOUR IMPORTANT FACTORS

Despite the simplicity of the torque loss diagrams discussed here, torque retention is a highly complex problem. Torque graphs, though good for comparing one gasket with another under the same conditions, depend on four factors: the load on gasket, cap screw length, thickness of the aluminum flange, and original gasket thickness. Until current tests reveal precisely how these factors are related, best gasket design for maximum torque retention must be determined by test.

Results of thermal cycling tests so far confirm, for dissimilar metal joints, a long-standing rule: specify the thinnest gasket that can be tolerated. The data in Table II shows that thinner gaskets result in lower hot torque loss—the loss that occurs between A and B on the torque spectrum. The data here do not quite agree with that for the same materials in Table I because the test fixture was slightly different, using a single flange bolted to a flat plate. As in all the results reported here, however, these data are based on repetitive tests and are known to reflect statistically significant changes, and not simply experimental error.

Longer cap screws help cut torque losses too. Table III shows the effect of increasing the active length of the bolt. Active length means the distance from the under side of the head to the surface of the threaded flange. This effect is to be expected, since the longer bolts load up less for a given amount of additional gasket compression—that caused by the faster expanding aluminum. Thus, as the gasket creeps during constant temperature operation, the loss in loading will be less for the longer bolt. Unfortunately, all designs will not permit longer bolts because of space limitations.

A third but less effective way to decrease torque loss is to specify aluminum bolts instead of steel ones. Although this compensates fully for contraction effects on cooling—ironing out the torque break at *B*—the lower yield strength of aluminum means lower permissible gasket loading and this may mean sealability is compromised. Appropriate testing will tell the story here.

EDITOR'S NOTE: Other articles on gasket materials and design include: "What's New About the New Papers," Feb 16, '59, p 50; "Flange Design and Gasket Selection," Design Digest Issue Mid-Sept '58, p F2; "Metal Gasket Design," Design Digest Issue Mid-Oct '57, p F12; "Gaskets That Are Sprayed On," Oct 14 '57, p 90; "Gasketed Joints for Electrical Equipment," Mar '57, p 183.

REPRINT of this article can be obtained for your reference file by checking No. E83 on one of the Reader Service cards bound in this issue. For other reprints available see "Current Reprints" listings in this issue on page 103.

These parts show that tantalum—because it's so ductile—can be stamped, drawn, rolled or spun. But how do you get good welds? And what about molybdenum, tungsten, columbium? Here's what you should know . .

before tackling the REFRACTORY METALS

ALAN F BUSTO, *welding engineer*
Fansteel Metallurgical Corp

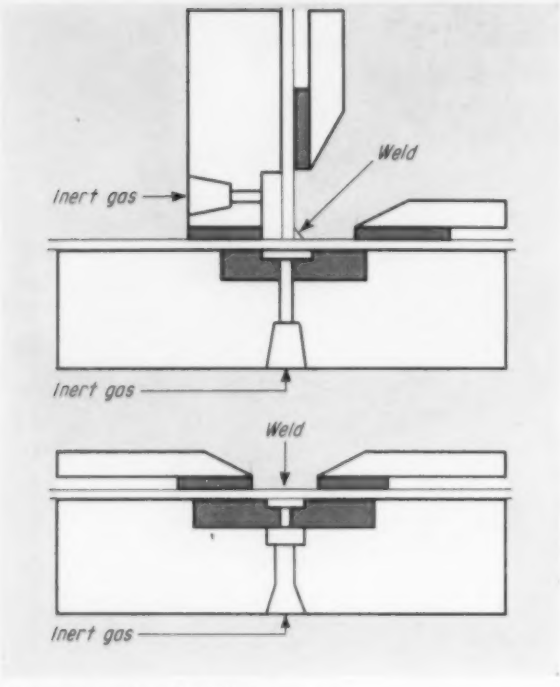
Growing popularity of the four so-called refractory metals requires design to begin looking at them more carefully. It is no longer practical to see only the similarities among columbium, tantalum, tungsten and molybdenum. They also show important differences in properties–and these must be considered in fabrication techniques such as welding.

High melting point is the outstanding characteristic possessed by all four. Their unique combination of helpful mechanical properties at elevated temperatures, along with their useful electrical and chemical behavior, is finding more work for them to do. But as their usefulness increases, it highlights the fact that, for fabrication, they really fall into two groups.

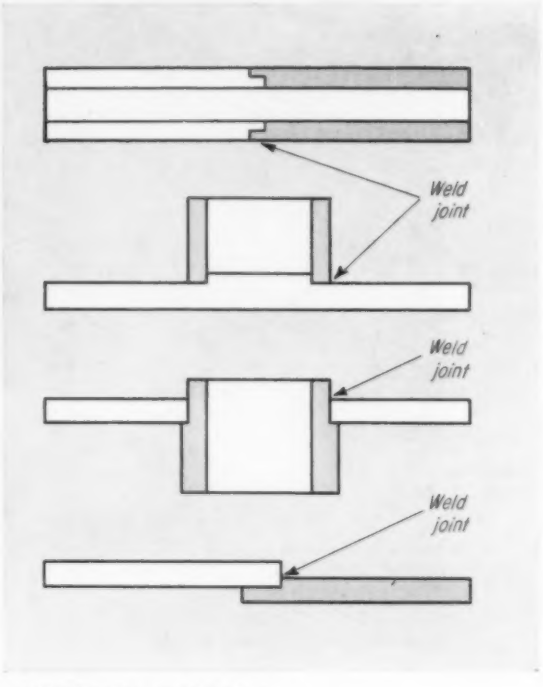
The tensile strengths of columbium (Cb) and tantalum (Ta) are about 40,000 psi; for tungsten (W) and molybdenum (Mo) they are above 100,000 psi. Cb and Ta have about 35% tensile elongation; Mo has 15%; W has practically no ductility at all. Another big difference is in elastic modulus–for Cb and Ta it is 12.4 and 27, but for Mo and W it is 42 and 50.

Forming Them

An important place where the differences between the two pairs shows up is in formability. Tantalum and columbium can be formed easily whereas tungsten and molybdenum resist plastic deformation. Ta and Cb in cold-working can be reduced 60 to 80% before they re-



Leave room for the fixtures . . .
when welding large parts outside a sealed chamber. These need from 1/8 to 3/16 in. clearance on each side of weld. Inserts (shaded area) which clamp the sheet material are copper for chilling, or stainless steel when weld should retain preheat.



Self-aligning weld joints . . .
overcome disadvantages of awkward assembling in sealed weld chamber. A drawback, however, is danger of incomplete weld penetration—this can lower strength of joint.

quire annealing. Mo and W can be formed slightly at room temperature when in the fibrous, worked condition, but are quite brittle when annealed or recrystallized. Fortunately, these are ductile at elevated temperatures—sheet molybdenum less than 0.020 in. can be formed by bending or rolling between 300 F and 400 F, and tungsten between 800 F and 1000 F. More severe forming, such as deep drawing on heavier sheets, must be done above 1400 F for Mo and 1700 F for W. Oxidation will occur in air at these temperatures, so reducing-furnace atmospheres should be used, and the forming time in air kept to a minimum.

Welding Them

The differing physical characteristics also split the refractory metals into two welding groups, as described below. However, all four metals also have some behavior in common—high melting points and rapid oxidation in air at welding temperatures. Avoiding contamination calls for the tungsten arc inert gas (tig) process using helium, argon, or a mixture of the two. Here, the gas excludes air from the molten puddle and prevents embrittlement that results from absorption of oxygen and nitrogen.

Where maximum weld ductility is required, it is best to use a welding chamber that can be purged of air and filled with inert gas. This enclosure is sealed but allows visual observation. With its welding system, it has arm holes or remote control to manipulate the weldment.

Welding fixtures within the chamber keep the components in correct alignment. In many cases, joints can be designed to be self-aligning so that light clamping and preliminary tacking is adequate. Without such alignment, more complex fixtures such as internal expanders, external clamps, or hold-down fingers must be used. Fixture design requires clearance for flow of inert gas around heated surfaces. If the product has a sealed cavity it must either be assembled after purging or have weep holes for gas circulation during welding.

If size or shape of the weldment makes a welding chamber impractical, the heated surfaces can be protected by gas-backed fixtures which not only hold the work in alignment, but chill it to limit the heat-affected area, exclude air and bring inert gas to the weld zone.

Although such fixtures seldom give ductility equal to that of welds made in an inert chamber, the difference is negligible for automatic or semiautomatic setups. Manual welding outside the chamber introduces too many uncontrolled variables so should be avoided where minimum contamination is required.

The Two Welding Groups

The same grouping that characterizes formability also appears when welding. Tungsten and molybdenum are

normally used for structural purposes after being made ductile by rolling and stress-relieving. This working gives a directional fibrous structure that supplies the ductility. Heating above the recrystallization temperature will remove this structure and its ductility. This is why annealing between processing steps should avoid recrystallization. A weld is brittle because it is a fully recrystallized structure. Therefore its ductility cannot be restored by heat treatment. Subsequent working of the weld, such as rolling, would raise its ductility–but normally a fabrication cannot be rolled. So, filler material should be added to make a large weld bead. This does not impart more ductility but does shift the weak point away from the brittle weld to a more ductile area.

Tantalum and columbium, in contrast, lose their ductility and cold-working increases their strength. Annealing by recrystallizing restores their ductility. Their welds, if not contaminated, are also ductile.

Design of Weldments

Product designs for tungsten and molybdenum must get around the brittleness of weldments at room temperature. If possible, the welds and weld joints should be kept stressed in compression until they receive ductility at higher temperatures. This compression can be had with tantalum or stainless steel supports. Because tantalum and steel have higher coefficients of expansion than the Mo and W, degree of support will diminish as temperature increases, transferring the high-temperature stresses to the now ductile Mo or W.

When welding the same two metals, the clamping loads must be compressive. When welding is finished, clamps should be quickly released to allow the structure to cool unstressed. Another method is to overform a circular part so the weld will be constantly under a compressive stress.

Preheating the fixture will prevent weld-cracking. This is a must for welding sections thinner than 0.025 in. Preheat should be sufficient to raise the metal part above its ductile transition temperature.

Tantalum and columbium, while they have enough room-temperature ductility not to require preheat in welding, also must not be heated in air above their oxidation points for any reason. The diffusion rates of oxygen, hydrogen, and nitrogen are so rapid that heating in air would embrittle entire thickness of parent metal. By contrast, though molybdenum and tungsten oxidize rapidly on the surface, they are not structurally affected by heating. They do not oxidize internally because gaseous diffusion into these metals is slow.

Thickness Limits

The upper limit of a square butt joint is dependent on the amount of weld penetration. A thicker joint, where needed, can be made by grooving one or both abutting sheets. In welding thick molybdenum and tungsten the root pass must have sufficient added filler material to prevent cracking.

The lower limit of thickness is controlled by the accuracy of alignment and controllability of the welding variables such as arc current, arc voltage and weld speed in the cases of tantalum and columbium. The fact that stainless steel is being welded at thicknesses below 0.001 in. gives confidence that foil of tantalum and columbium can also be welded. By contrast, welding molybdenum and tungsten below 0.020 in. is extremely difficult. Because of their brittle nature below the ductile transition temperatures, preheat and postheat must be maintained carefully. It is also necessary to avoid bending, torsion, and tensile loads.

EDITOR'S NOTE: For more on properties of columbium and other unusual metals:

"Exotic Metals Seek Employment," Mar 17 '59, p 66—describes nine relatively rare metals, and compares their electrical and structural properties in a table that covers 17 common and rare metals.

"Heavy Metals Solve Weighty Problems," July 21 '58, p 62—how to put high-density tungsten materials to work tackling new and complex jobs.

coming in the June 8 issue . . .

special report on ASSEMBLY METHODS

A solid package, 16 pages, of illustrated how-to's that will help you solve some tough assembly problems, or spark answers to others.

Low-cost, efficient and ingenious assembly methods often make the difference between success and mediocrity in a new product. The process of finding a better method, as in most engineering progress, is usually one of evolution. Here are some starting points—or catalysts for further progress. They recognize that the selection of the fastener is always dependent on the function the fastened parts are required to perform, and the detail design of the parts to be joined. This special report, prepared by associate editor Doug Greenwood, presents 13 different groups of assembly methods, a valuable check list of *all* assembly methods and devices, and an annotated list of earlier articles in PRODUCT ENGINEERING that supply detailed background data on a variety of specialized fastening methods.

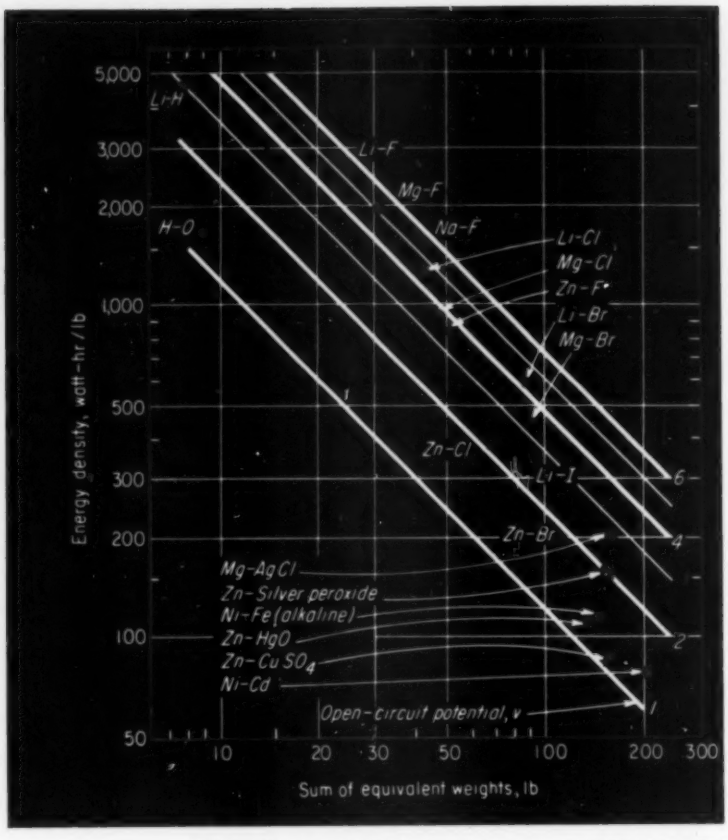
—in the June 8 issue

a look in the future . . .

HIGHER-ENERGY BATTERIES

A report on potent electrochemical couples that may give power packs only 1/10 as heavy as today's best commercial batteries

E C PITZER
General Engineering Lab
General Electric Co, Schenectady



Rating the new batteries . . . Max outputs under theoretical conditions compare energy densities of electrochemical pairs. Actual energies of commercial batteries (cluster at lower right shows typical pairs) are given in table.

Present-day commercial batteries, whether primary (non-rechargeable) or storage type, **have outputs of less than 60 watt-hours per pound** of total battery assembly. This over-all "energy density" is barely enough to meet present requirements of the Space Age–and the requirements may double in the near future.

Other products besides space vehicles have great need for high power in small packages. Some are: electric trucks, mine locomotives, railroad cars (lighting and air conditioning), engine starters, emergency lighting, telephone systems, planes, ships, submarines, portable radar, and electric automobiles (*PE*—Nov. 24 '58, p 27).

Better batteries must be developed; and the answer may be found in cells with high-energy electrochemical couples–also called "electrode pairs." Many pairs give energy densities measured in 1000's of watt-hr/lb. Some of these energies are plotted in the accompanying graph along with max theoretical values for commercial types.

Batteries made with these high-energy couples are not off-the-shelf items; and very few are even obtainable. It is difficult to store the chemicals that produce the reaction; and even more difficult to arrange them in a workable cell. Most high-energy electrode elements react violently with water, and require nonaqueous electrolytes.

CELL EQUIVALENT WEIGHTS

All electrochemical couples can be evaluated theoretically (as in chart above) in terms of energy density in w-hr/lb. This is a relationship which is the open circuit potential multiplied by 12,200 and divided by the sum of equivalent weights—a measurement defined later.

Open-circuit potential, E, depends on the combination of chemicals chosen, and can be predicted for each battery type by referring to the electromotive series in a chemistry handbook. Observed voltages, however, are usually lower than theoretical values. Most practical cells have open-circuit potentials of less than 2.5 v; above that value, hydrogen or oxygen (depending on the chemicals in the reaction) may be released from the electrolyte.

The constant, 12,200, and the **"sum of equivalent weights"** are derived from electrochemical relationships and hold true for any couple: Here is how these relationships are derived:

The capacity of a cell is measured in coulombs (ampere-seconds). Each ion in solution can give up or accept a charge whose value in coulombs is a function of

Energy density of commercial batteries

("Actual" data is from catalogs)

	Sum of equiv. wts, lb	Voltage		Energy density w-hr/lb	
		Theory	Actual	Theory	Actual
Mg-AgCl	156	2.59	1.6	198	15
Dry Mg-AgCl (water-activ.)	156	2.59	1.3	198	51
Zn-Silver peroxide	155	2	1.4	158	54
Ni-Fe (alkaline)	148	1.35	1.2	112	12
Zn-HgO	139	1.34	1.3	110	51
Zn-$CuSO_4$	156	1.1	1.1	85	—
Ni-Cd	204	1.32	1.2	79	11

valence and not of atomic weight. It follows that chemicals with low atomic weights and high valences will have greater capacity per pound of weight, and become the key to lightweight batteries.

The total energy of a battery is the product of open-circuit voltage and capacity: total energy, w-hr = ($E \times$ amp-sec)/3600.

Finally, to compare performance of different cells, the chemical reaction in each is compared with a hypothetical reaction in which approximately one pound of hydrogen (in form of ions) gives up all its charge—43.8 x 10^6 coulombs. The equivalent weight of a chemical is that weight needed to react with, displace or substitute for this amount of hydrogen and thereby participate in release of 43.8 x 10^6 coulombs charge—12,200 amp-hr. The **sum of equivalent weights** includes all the active chemicals in such a reaction. The chart for **energy density**, on opposite page, is the result.

PRACTICAL DESIGN LIMITS

Experience has shown that for a battery operating at max power, theoretical energy density of the active chemicals should be about five times that required for the total battery assembly. This is because no battery can be made entirely of active materials, nor can all the energy be gotten out of materials that are active. For example, if 100 w-hr/lb over-all energy density is expected, then the active chemicals should have a theoretical energy density of 500 w-hr/lb.

Cell dimensions, particularly the total area of electrodes exposed to electrolyte, will influence the rate at which battery energy can be discharged. Modern batteries get high rates by having porous or flaked electrodes with extremely high surface area.

Polarization, the accumulation of hydrogen on one of the terminals when appreciable current is drawn, impedes current flow. Some cells are designed with containment of air; the oxygen is able to depolarize the terminal if currents are not too high. At higher current densities, chemical depolarizers are essential; examples are potassium dichromate, manganese dioxide, cupric oxide, lead dioxide, nickel oxide and silver peroxide. They chemically combine with the hydrogen before it accumulates.

ROLE OF ELECTROLYTES

An electrolyte has a two-fold task: permits ionization of the battery chemicals; conducts the resulting current. **Aqueous solutions** are found in the great majority of commercial cells, and work well. Even the experimental hydrogen-oxygen fuel cell (*PE—Feb 17 '58, p 18*) can have an electrolyte of potassium hydroxide in aqueous solution.

However, many of the potentially useful elements in the high-energy range are not stable in contact with water—for example, lithium, sodium, chlorine, fluorine. Nonaqueous electrolytes must then be selected. For lithium and sodium, a suitable electrolyte is liquid ammonia or methylamine. For fluorine, liquid hydrogen fluoride is compatible.

Gaseous electrolytes theoretically will work with any of the high-energy metals discussed in this article. For example, ammonia gas under moderately high pressure will dissolve ammonium thiocyanate to become an electrolyte. Batteries of this type can be stored without the gas; no activity begins until the gas is added.

Fused electrolytes such as sodium hydroxide and sodium nitrate have good possibilities. But external heat is needed—at least at the start—and no electrical potential results until melting is complete. A battery cell with melted sodium hydroxide electrolyte, using magnesium and carbon electrodes, has an open-circuit potential of about 1.8 v.

Ionization in some nonaqueous electrolytes falls short of that attained in aqueous solutions; also, the cell's electrical resistance can be greater. Discharge rate (current drain) might therefore be less.

Effective operating potential and total useful capacity of a cell depend not only on the simple chemistry of the reaction, but also on external circuit resistance, internal cell resistance, and duty cycle. Performance comparisons between batteries can be made only if all important conditions are specified. For operation at max power, external resistance must equal the internal; under this condition, the operating potential is one-half the open-circuit potential. At light loads, open-circuit potential is approached but never reached. Test criteria are given in National Bureau of Standards Circular No. 559, for dry cells.

REPRINT of this article can be obtained for your reference file by checking No. E82 on one of the Reader Service cards bound in this issue. For other reprints available see "Current Reprints" listing in this issue on page 103.

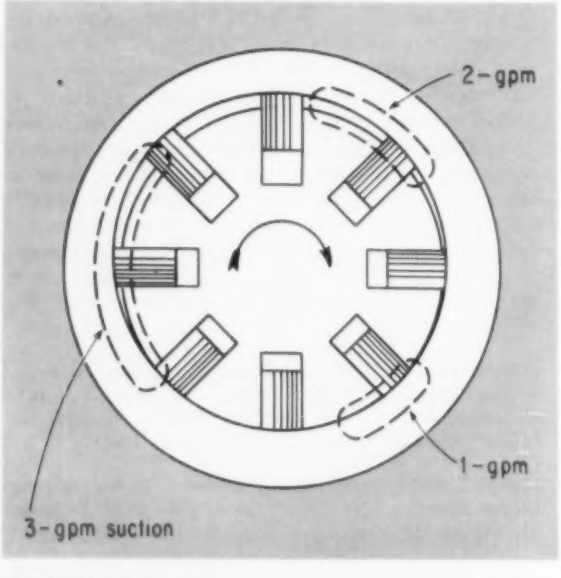
EDITOR'S NOTE: These previous articles cover the field for existing batteries: "Dry Cells," Feb 17 '58, p 72, evaluates the popular commercial Leclanche cells on bases of NBS qualifying tests, and describes can and wafer designs; "Midget Batteries," May 12 '58, p 72, compares performance and price of all miniature primary and secondary battery types including Leclanche, mercury, indium-anode, solid-state, nuclear, nickel-cadmium, and silver-zinc.

For future power packages involving nuclear energy and fuel cells, read "Taming Tomorrow's Power Sources," May 4 '59, p 29.

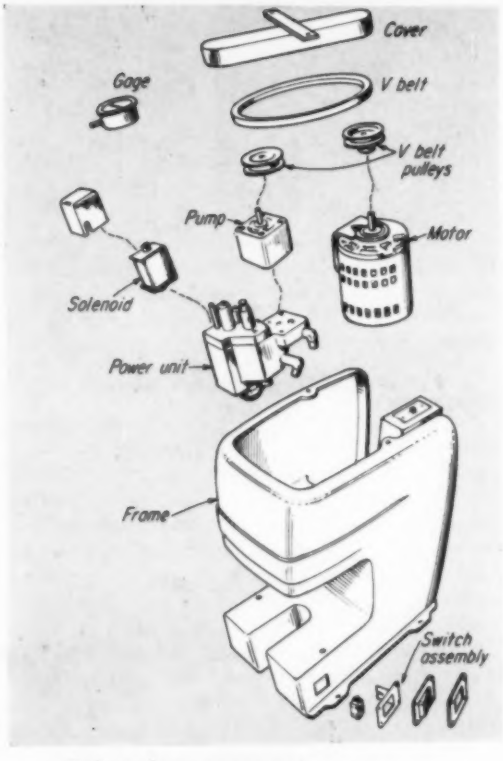
Packaged Press Squeezes Costs

One-piece frame plus unitized power package reduce cost and simplify construction of bench press. Dual-volume pump produces high cycle rate and rapid rise to operating pressure.

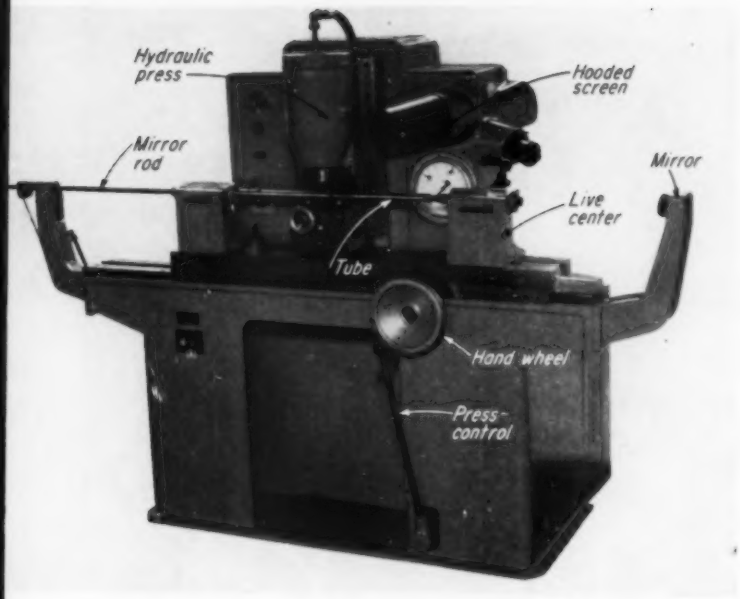
These compact presses are self-contained, need no anchoring, operate from 110/220-v single or three-phase line. Model "A" Multipress is produced in 1 and 2-ton models by Denison Engineering Division, American Brake Shoe Co, Columbus 16, Ohio.



Dual-volume pump . . .
has 3-gpm suction, 2-gpm delivery at 250 psi and 1-gpm delivery at 1000 psi. Both outputs are connected to the hydraulic cylinder for stroke; at end of stroke a solenoid-actuated valve closes the low-pressure port and the 1-gpm, 1000-psi output is applied to build up and maintain the ram pressure.



Only a few components . . .
are needed to assemble the press. Frame contains built-in hydraulic reservoir plus mounting for motor, power unit and controls. To reduce size and cost, power unit is designed as one component including dual-volume pump, solenoid valve and hydraulic cylinder—and installed as a package. A single V-belt drives the pump. Gage mounted on power unit is used to set regulator for ram pressure to any value down to 250 psi.

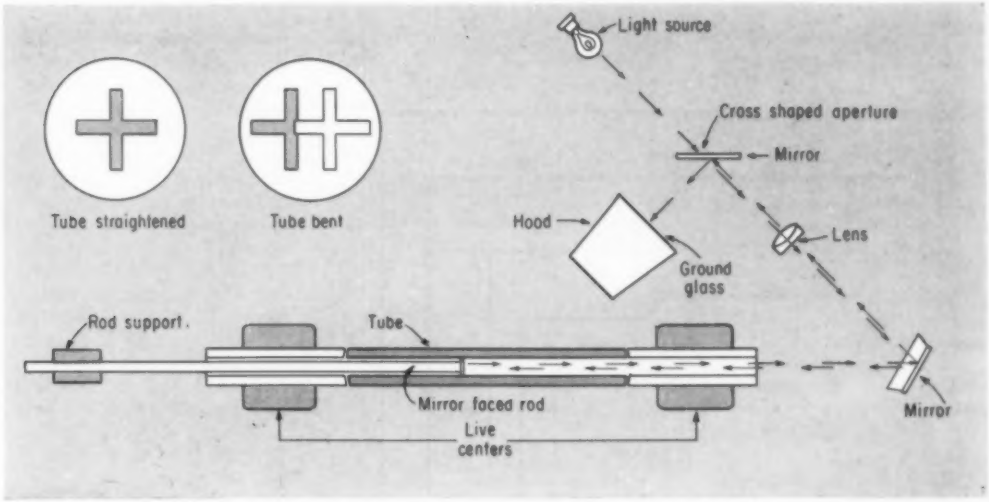


Spring-loaded . . .
live centers, with hollow spindles, hold the tube during checking. Handwheel moves ballbearing-mounted table and live centers across pivoted anvil of press to permit inspection-straightening of entire tube length. Large dial indicates force being applied by press. Hood over ground-glass screen permits operator to check tube alignment in lighted shop areas. Mirror-faced rod reflects light back through tube for checking.

Swallowed Mirror Guides Tube-straightener

The tubes are gun barrels straightened in a hydraulic press. The mirror-faced "ram rod" is part of optical system that permits checking the bore for alignment—without need to remove tube from press.

Primarily designed for rifle and machine gun barrels, straighteners can handle tubes from 5/8 to 1¾ in. dia. Between 20 and 25 lengths of tube can be finished per hour. Produced by Berlin-Luebecker Maschinenfabrik, Lubeck, Ger.

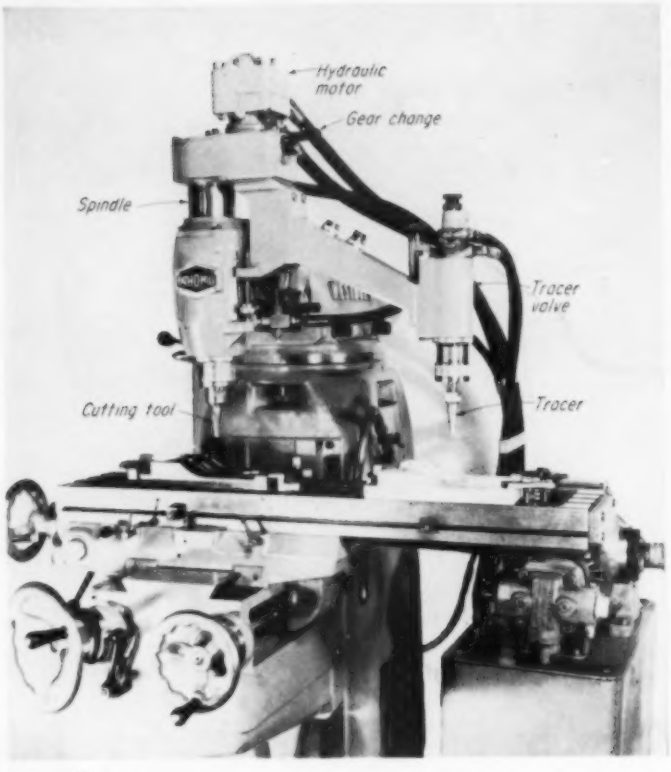


Mirror-faced plunger . . .
is inserted into bore of tube mounted between live centers. Light source behind press is projected through a cross-shaped aperture in the mirror. Using externally mounted mirror and the mirror-faced plunger, the light pattern is reflected back to the hooded ground-glass screen. When cross-like images coincide, tube under test is perfectly straight.

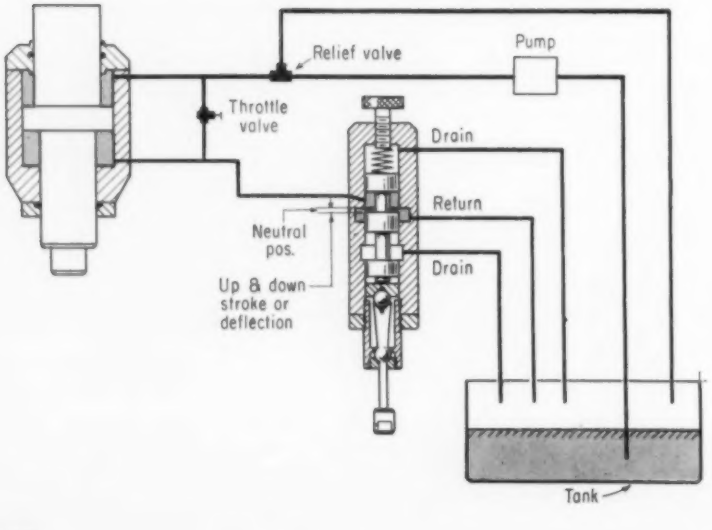
Floating Spindle Absorbs Backlash

Dual-purpose component in copy milling head eliminates moments generated by offset actuating cylinders. A single hydraulic valve controls all quill motion.

Four bolts mount this copy milling head on vertical milling machines, universal mills or slow table-speed planers. Standard 8-speed drive or infinitely variable hydraulic transmission with speeds from 40 to 3000 rpm are available. Path-O-Mill, with 2-hp output and 4-in. quill stroke, is produced by Pathex Ltd, Toronto, Ont, Canada.



3-D mill . . .
is used primarily to produce steel dies for die-casting and forging from patterns. Vertical motions of cutting tool are controlled by feeler mounted in the tracer head; all horizontal movements are provided by the milling-machine feed mechanism. Stepless speed control is given by a vane-type hydraulic motor driven by a variable-volume pump. The gear change gives speed ranges of 50-550 rpm and 270-3000 rpm. Hydraulic power is provided by a variable-volume, constant-hp pump with built-in relief valve. This permits the operator to adjust cutting speed for maximum tool life by observing chip color, tool sound and vibration.



Dual-purpose spindle . . .
serves as hydraulic piston and tool holder. Two bearings 12 in. apart are lubricated under pressure to fill the clearance between spindle and housing. This gives constant friction, eliminates side play and damps vibrations. Simplified hydraulic circuit uses a single valve in the tracer to give balance between the pressure differentials created by the throttle valve.

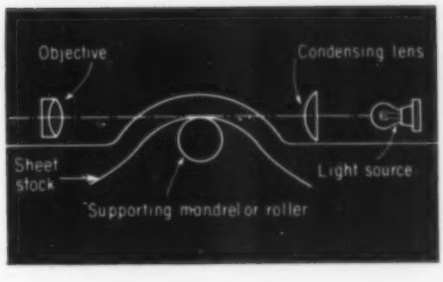
When the spindle is at rest, hydraulic fluid is pumped through the throttle valve and to the partially opened tracer valve. From this valve the fluid returns to tank When the tracer rises, its valve closes and fluid-flow through the throttle valve stops. Now pressure is equal on both sides of the throttle valve and hydraulic piston. Since the lower piston has a greater face area, the spindle rises. When the tracer drops, its valve opens fully, discharging hydraulic fluid to the tank, and reducing pressure on lower side of the throttle valve. Pressure on the smaller, upper piston face forces the spindle downward.

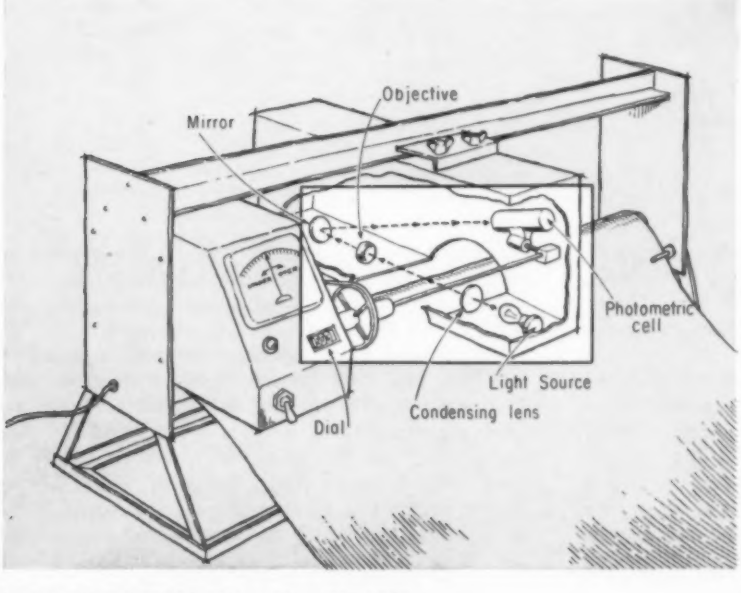
Suspended . . .
over sheet material to be checked, gage is first zeroed on empty roller, then set for thickness of stock running over roller. Motor-driven 5-digit dial indicates the setting in thousandths of an inch, and meter indicates variations from the nominal thickness. Usual scale of meter is 0.0001 in. per division but various indications can be used depending on tolerances involved.

Light Scans Thickness of Material

Optical-type gage doesn't actually contact the material being checked, so is unaffected by its speed or properties. The instrument is sensitive to variations of 0.0001-in. thickness of sheet, foil or webbing.

Single or multiple installations may be used to check thickness at one or more points across the width. Warning lights or audible signals can be incorporated, or connections made to thickness or coating controls for fully automatic operation. Mark N Thickness Gage is produced by Mark N Laboratory, Bethel, Conn.





Optical principle . . .
is key to operational flexibility of gage. Light passes through condensing lens, across material being tested, through objective lens—then is reflected from mirror to photometric cell. Changes in thickness of the material being tested vary the amount of light reaching photometric cell and are indicated on the meter after passing through a balancing circuit. Motor-drive moves photometric cell back and forth by means of an inclined screw drive to alter its elevation and give the desired thickness setting.

Properties such as dielectric constant, conductivity, absorption of radiation are not involved in the measurement, therefore the gage measures stock of any type without modification. Opacity does not influence measurement because the material is tangentially illuminated. Gage is particularly suited to quality control of coating processes where variations in electrical or absorption characteristics eliminate usual methods.

THE OTHER SIDE OF THE PRECISION CONTROVERSY. . .

a workable approach to GEAR TOLERANCES

WILLIAM A WIEGAND, president
Dynamic Gear Co. Inc, Amityville, NY

THE AUTHOR
checks a TCE tape reading of a Precision Class III gear hobbed on the new Barber-Coleman 2½-4 machine.

Admitted that there is room for better methods of specifying the precision of gears. But just what's the best approach to the problem?

As a service to readers, PRODUCT ENGINEERING recently presented an eye-opening article, "New Standards for Gears Span Wide Range of Quality." It proposed doubling the number of AGMA classes to include an "ultraprecise" group of gears which the author, L. D. Martin, considered of growing importance. Mr. Martin is chairman of the ASA Subcommittee on Fine Pitch Gears, and member of three AGMA committees; his article (Dec 22 '58, p 46) aroused considerable discussion.

We now present an article by a prominent gear manufacturer who offers a counterproposal to Mr. Martin's plan. Mr. Wiegand believes the need for ultraprecision hasn't arrived yet and additional classes will only add to the confusion. He goes on to offer an approach to what he says gear designers really want—tables that directly give shaft-center distances and backlash values for each present class of gears.

Mr. Wiegand will be remembered for his article, "7 Rules Simplify Instrument Gear Specification," Nov 25 '57, p 80, which recommends holding requirements to a minimum. Readers who want a comprehensive analysis of the AGMA standards will find it in George Michalec's article, "Methods of Specifying Precision of Spur Gears," Nov '56, p 135.

Are the gears you buy off the shelf not precise enough? Louis Martin proposes a standard that extends the AGMA classes to include an "ultraprecise" class of gears. But do the majority of designers and engineers need gears made to such fine tolerances?

Our experience shows they do not. Most problems of the gear designers—especially in the instrument field—stem from difficulty in understanding the center-distance specifications in the AGMA standards. What the gear designer really wants is simply this: to be able to specify the class of precision—say, "Precision II" gears—and then consult a table for (1) the exact distance he should locate the shaft centers on his product; (2) the tolerance on this center-to-center distance; and (3) the amount of backlash he can anticipate—because backlash, and sometimes lack of backlash ("binding" in a gear train) is one of his biggest headaches.

For example, suppose you are designing a gear train with two 1-in., 14½° pressure-angle, intermeshed gears. The nominal center-to-center distance is 1 in. If precision is a requirement and gears in the Precision I class are specified, you should locate the centers 1.0004 in. apart with a tolerance of plus 0.0004 in., minus 0.0000. This will result in a backlash play ranging from 0.00021 in. to 0.00145 in. (which means an angular play or "lost

(TEXT CONTINUED ON PAGE 00)

GEAR AND BACKLASH SPECIFICATION—A PRACTICAL APPROACH

(Values shown in bold type are only for two intermeshed gears of 1-in. pitch dia)

FOR MEASUREMENT OVER WIRES

				Distance Between Shaft Centerlines			20° Pressure Angle		14½° Pressure Angle	
Precision Class	TCE	TTCE	Measurement Over .036-in. Dia Wires, and Tolerance	Nominal	Additive	Final	Minimum Backlash	Maximum Backlash	Minimum Backlash	Maximum Backlash
I	.001	.0004	$1.0506^{+.000}_{-.001}$	**1.000**	.0014	$1.0014^{+.0004}_{-.0000}$	.00029	.00276	.00021	.00196
II	.0005	.0003	$1.0506^{+.000}_{-.0005}$	**1.000**	.0008	$1.0008^{+.0003}_{-.0000}$	.00022	.00153	.00016	.00109
III	.00025	.0002	$1.0506^{+.000}_{-.0003}$	**1.000**	.0005	$1.0005^{+.0002}_{-.0000}$	.00015	.00095	.00010	.00068

WHEN MESHED WITH A 1.500-DIA MASTER GEAR

				Distance Between Shaft Centerlines			20° Pressure Angle		14½° Pressure Angle	
Precision Class	TCE	TTCE	Center Distance Meshed with Master and Tolerance	Nominal	Additive	Final	Minimum Backlash	Maximum Backlash	Minimum Backlash	Maximum Backlash
I	.001	.0004	$1.250^{+.000}_{-.001}$	**1.000**	.0004	$1.0004^{+.0004}_{-.0000}$	.00029	.00204	.00021	.00145
II	.0005	.0003	$1.250^{+.000}_{-.0005}$	**1.000**	.0003	$1.0003^{+.0003}_{-.0000}$	.00022	.00116	.00016	.00083
III	.00025	.0002	$1.250^{+.000}_{-.0003}$	**1.000**	.0002	$1.0002^{+.0002}_{-.0000}$	.00015	.00073	.00010	.00052

HOW TO USE ABOVE TABLES

The two tables given here are suggested as a quick guide—not as a standard—for gear trains where minimum backlash is desired. All values, with the exception of those in bold type, hold true for any size or pitch gear.

The values which vary are: (1) Measurement over wires. This varies with the size (pitch dia) of the gear and pitch. See *The New American Machinists Handbook*, pages 4-53 to 4-57, McGraw-Hill Book Co, NYC, for other values. The tolerance, however, remains constant for that particular class of gear. (2) Nominal center distance. This, of course, varies with size. (3) Modified center distance. This also varies with size; however, its tolerance remains constant for that class.

You can choose either table, depending on whether an over-wire check or center-distance check is specified. Select also gear class and pressure angle. The shaft-centerline column marked "Final" then directly gives dimension and tolerance between shaft centerline that you should specify on the drawing of the product or instrument. Backlash columns give range of backlash (max and min values) that can occur—not including, of course, play in bearings, etc.

Note that backlash values for 14½° gears are smaller than for 20° gears. These values can be converted to angular play, θ, in the gears by using the equation $\theta = 360B/\pi D$, where B = backlash, in., D = pitch dia, in.

OBTAINING THE VALUES

Here is the way the values in above table were calculated. The example is for Precision Class I.

Measurement over wires—Min Backlash

Assume pitch dia = 1.000 in., which is largest permissible value. Then measurement over wires is 1.0506 (obtained from machinist's tables or calculated).

Each pitch dia can have a runout of 0.0005 over nominal due to TCE which is 0.001 for this class. Therefore, for two gears meshed at their highest point, the center distance is:

$$\text{C.D.} = \frac{1.0000}{2} + 0.0005 + \frac{1.0000}{2} + 0.0005 = 1.0010$$

The gears should be mounted at a distance equal to nominal C.D. + TCE + TTCE. A plus tolerance is assigned to the C.D.; therefore, for tightest condition, distance between shaft centerlines = 1.0014. Clearance at point of tightest mesh is equal to 0.0004, and min backlash is: $B = 2(\Delta\text{C.D.})(\tan\theta) = 0.00029$ min.

Measurement over wires—Max Backlash

Assume each gear has min pitch dia of 0.999. Then measurement over wires is 1.0496.

$$\text{C.D.} = \frac{0.999}{2} - 0.0005 + \frac{0.999}{2} - 0.0005 = 0.998$$

The gears should be mounted at a C.D. as obtained before except tolerance is added. Therefore C.D. for mounting = 1.0018, ΔC.D. = 1.0018 − 0.998 = 0.0038 and B = 0.00276 max.

Center-distance check

If a 1.000 pitch dia gear is meshed with a master gear of 1.500 pitch dia, the nominal C.D. = 1.250. Because the tolerance on this mesh is −0.001, the C.D. with full TCE will vary from 1.2500 to 1.2490. With two gears, C.D. will vary from 1.000 to 0.998.

The gears should be mounted at a C.D. equal to nominal plus TTCE, with a plus-tolerance equal to TTCE. Thus, if the shaft distance is at a minimum (1.0004) and gears are meshed at highest points (C.D. = 1.0000), the ΔC.D. = 0.0004 and B = 0.00029 min.

For maximum backlash, the ΔC.D. = 1.0008 − 0.998 = 0.0028, which gives B = 0.00204 max.

motion" in one gear (holding the second gear stationary) of 0.024 to 0.165°. But nowhere in either the AGMA's present or Martin's proposed standard can this information be found. Consequently, many designers "play it safe" by purchasing the most precise gears that can be made in production—only to run into trouble anyway because of incorrect center-distance dimensions or tolerances.

THESE TABLES FOR WORKING DATA

This is why I have set up two tables (preceding page) which permit an engineer to specify a class of gear and immediately know what the center distance should be, along with resulting backlash. The AGMA specifications of total composite error (TCE) and tooth-to-tooth composite error (TTCE) are also given.

One table is for cases where a measurement over wires is specified; the other, where a center-distance check is specified. These tables could be as much a part of gearing standards as the bore tolerance is a function of a particular class of gear.

This Problem Ring a Bell?

As an example of what the engineer in the field faces today—this letter speaks for itself. It was sent to the Dynamic Gear Co by C. O. Burns, project engineer, Bendix Radio, Baltimore.

"Dear Sir:

"In using your catalog, I have difficulty in determining exactly what I would have if I purchased your gears.

"The problem is how to determine what backlash I would have for a specific center distance and also how I would inspect your gears. Assume I purchase from you a gear of 48 Pitch, 96 Tooth, Precision II. What would be the maximum and minimum indicator reading on a variable center distance fixture, if the master gear I use on the fixture is a perfect 2.000 in. P. D. gear with zero runout, and the indicator gage is zeroed on 2.000 in. center distance?"

Gears specified to a measurement over wires (sometimes called pins) are more economical to produce and inspect than gears specified to center-distance measurements. This is because inspection with over-wires requires only a micrometer, a set of wires, and bench centers to hold the gears.

Equipment for a center-distance check, on the other hand, is very costly, requires specially trained personnel to interpret the results, and can be found in relatively few locations other than the plants of gear-manufacturers and large users. But a tighter center distance can be safely specified (this is seen by comparing the two tables).

OMIT CLASS MODIFIERS

Consideration should also be given to eliminating the class modifiers, such as "Commercial" Class II or "Precision" Class II. The classes should run in straight numerical order starting from zero, which may have no given limitations. Next would be Class I similar to the present Commercial Class I. Thus Precision Class I would become simply Class 5, etc. The descriptions as currently specified in the AGMA lead to some confusion, as evidence the case of Commercial Class 4. This is a precision class of gear and could be used to good advantage more frequently, but the word Commercial frightens many designers from specifying such a gear.

Mr. Martin's logarithmic sequence is to be complimented. Good thought and sound reasoning are evidenced here. The numerical approach to class may fit this sequence very nicely.

THE IMPRACTICALITY OF ULTRAPRECISION

Our company is supplying vast quantities of Precision Class I and Precision Class II gears. To fabricate Precision Class III gears in production quantities and offer them at production prices, meticulous care must be taken not only in actual tooth cutting but also in manufacture of the blank. Presently we are producing these gears on the new Barber Coleman 2½-4 Hobbing Machine which has work spindle to hob spindle accuracy within 20 seconds. This in turn holds indexing error on a 2½-in.-dia gear to within 0.00014 in.

However, inspection of these parts remains a slow, tedious, cautious process because we are examining production gears that have about the same accuracy as the master with which they are being checked. Bearing this in mind, I cannot appreciate the need for Mr. Martin's "Ultraprecision" Classes which go as fine as 0.00001-in. TCE. Because I am a major supplier of fine-pitch gears (48 through 120 DP) people would expect my organization to supply some of these ultraprecision fine-pitch gears. But right now I would not know how to even handle an Ultraprecision Class II gear on a semi-mass production basis, let alone Class VII. Anything approaching such accuracies must be done as a laboratory job and I do not believe that we need such standards for the type of work carried on in modern labs. There would even be a problem in inspection. Precision Class III Master Gears are readily available and we have been advised by the suppliers that 0.0001-in. accuracy can be provided; but this accuracy would not be good enough to check Ultraprecision Classes IV to VII.

Probably one day these standards and specifications will be required, but they certainly appear premature now. For example, one might propose a neat, compact set of traffic laws to govern rocket travel, and few will deny the possibility of such laws being needed some day. But who would want to be burdened with them at present?

REPRINT of this article can be obtained for your reference file by checking No. E81 on one of the Reader Service cards bound in this issue. For other reprints available see "Current Reprints" listing in this issue on page 103.

from human-factors studies . . . .

THESE 3 CRITERIA for Readable Panel Markings

Labels . . . counters . . . legends . . . identifying tags—all are functional on an instrument panel. They'll do their jobs best if you heed this author's advice for lettering, placement and information content.

G A PETERS and B B ADAMS, *consultants*
Santa Monica, Calif

If panel markings are to perform their job with most efficiency, three questions must be answered: What kind of lettering is most visible? Where should it be placed? What words should be used? The answers can be found from data developed in human-engineering laboratories. There, psychologists and engineers have simulated a variety of conditions to assure that the data will apply to almost every situation occurring in actual practice.

Primary aim of this research is to reduce time delay—between the time an operator receives a signal to act and the time the action is performed. Human limitations set an irreducible minimum on response time, but lettering that is too small and labels that are too close together can increase this time by a factor of three to ten or more.

Time delay can be reduced by training—but only if the equipment will be operated repeatedly by the same man. If it is to be operated by persons with very little training, labeling of controls must be consistent with the number of errors allowable.

Other considerations are: Will operators have special knowledge or skills, or will they be men with widely varying experience? Will all operators speak the same language?—if not, it may be necessary to invent symbolic or pictographic markings.

Another human-factors consideration is environment. Will ambient illumination be high or low? Will the operator wear protective clothing or equipment that may interfere with his ability to see and read panel markings? If the panel is mounted on mobile equipment, what precautions will be necessary to insure readability when in motion?

Some equipment requires performing operations in sequence (during startup and shutdown, for example). This operating sequence can be indicated by proper labeling and careful grouping of controls.

From such underlying considerations have come the following recommendations for answering the three basic questions.

BEST LETTERING FOR VISIBILITY

Height of letters and numerals can be found from the following formula:

$$\text{Height (in.)} = 0.0022\,D + K_1 + K_2$$

where D is viewing distance, in., and K_1 is correction factor for illumination and viewing conditions according to the following table.

Illumination, ft-candles	Reading Situation	K_1
Above 1.0	Favorable	0.06
	Adverse	0.16
Below 1.0	Favorable	0.16
	Adverse	0.26

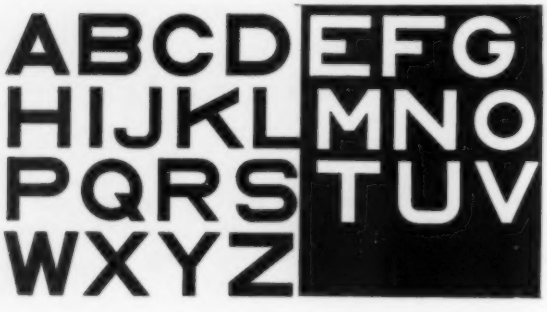
Correction factor K_2 depends on importance of the information. For emergency labels, counters, scales and legend lights, K_2 is 0.075; for other panel markings, K_2 is zero.

The formula does not apply for viewing distances of less than 16 in. For operators at standard consoles, D is 28 in., and K_1 is 0.16. *(CONTINUED, NEXT PAGE)*

PANEL MARKINGS (continued)

Character design should be a plain, block-style, sans-serif typeface. Two standards are suggested: NAMEL (shown below) and MS33558 (ASG) Military Standard, Numerals and Letters, Aircraft Instrument Dials. If either of these standards is not used, block letters with the following average dimensions are recommended:

letter width = 0.6 height
min distance between letters = 0.125 height
stroke width = 0.125 height
numeral width = height



Further recommendations for lettering on all panel labels, legend lights and scales:

- **Use all capital letters;** do not mix upper and lower case except for extended material such as instruction tags, specification plates, etc.
- **Specify etched or embossed letters;** avoid stamped, silk screened or printed letters. Printed decals are acceptable but less resistant to abrasion and wear and tear of continued operation.
- **Black letters on white background** are best if brightly illuminated (above 1.0 ft-candle); white letters on black background are most readable in poor illumination.

INFORMATION CONTENT FOR RAPID SCANNING

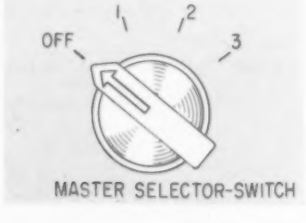
If confronted with the two selector switches below, an operator would be less confused by the one in the lower sketch. Labeling on upper switch can be improved these two ways:

1. Choose descriptive labels that describe task, equipment or system function. Labels that tell obvious facts don't give the operator information he needs.
2. Don't use numbers or letters on switches or switch positions unless such designations have a descriptive meaning. Concise titles of one or two words are better.

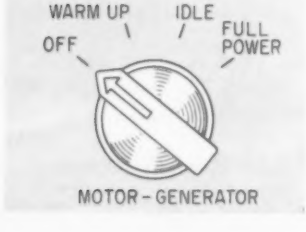
And when specifying labels for other controls, keep these pointers in mind:

3. Fully label controls and displays to include both function and mode of operation. Toggle switches should have ON-OFF escutcheon plate or have ON and OFF engraved on the panel to indicate direction of actuation.
4. Strive for brevity and simplicity in choosing label words. Use only common words and avoid abstract symbols, nonstandard abbreviations, and names for different parts that might be confused because of similarity.
5. Label electrical terminals with the same code symbol as the wire which connects to it.
6. Code the maintenance test-points so that, with the instruction manual, checking and trouble-shooting procedures can be followed in proper sequence.

WRONG



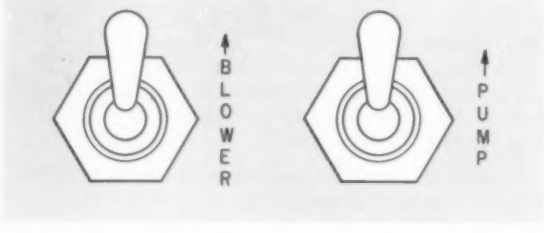
RIGHT



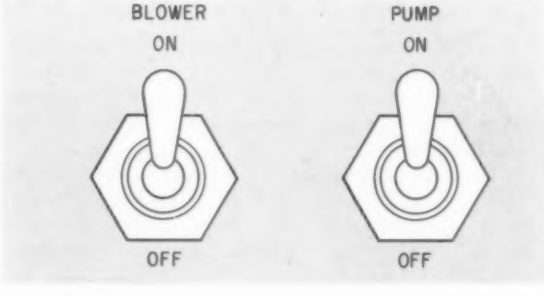
BEST PLACEMENT OF LETTERING

Readability will be improved and confusion eliminated if seven basic rules are followed. Three of them are illustrated in the pair of switchplate sketches below.

WRONG



RIGHT

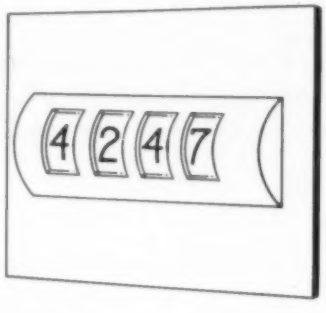


1. Place labels above or below (preferably above) each control—but be consistent.
2. Do not put labels between controls. This can cause confusion with other controls or other labels.
3. Orient labels horizontally. Do not use lettering which must be read vertically—top to bottom or bottom to top.

In other situations, the following tips will help in plac-

THESE, TOO, NEED EASY READING

Counters and legend lights are a special kind of label. For best readability, they should meet the general recommendations for labels in addition to those listed below.



Counters

Mount a counter with drums close to panel surface—to maximize viewing angle, eliminate shadows, and reduce parallax.

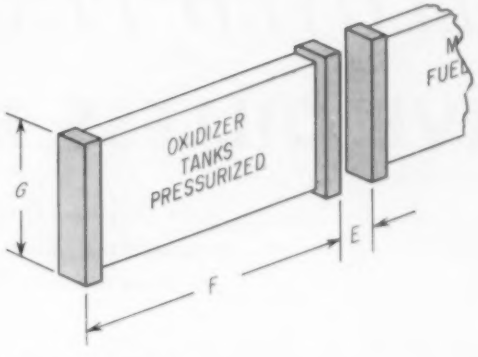
Orient counter horizontally so numerals are read from left to right.

If last digits are not essential to job performance, replace with stationary zeros.

For consecutive reading, numbers should not follow each other at a rate faster than two per second.

Numerals should snap into position, centered in viewing window.

Upward movement of the drums should result in numerical increase.



Legend Lights

Specify legends engraved in black letters on nonreflecting white background. For color-coded indicators, insert filters behind white background.

Use color coding sparingly to avoid "Christmas tree effect" which only detracts from its attention-getting value.

If flashing indicators are used, recommended flash rate is 3 to 5 cps (off-time equal to on-time). Flasher should be wired so indicator remains on if flashing device fails.

Recommended max and min dimensions are: $F = 0.875$ to 3.00 in., $G = 0.5$ to 1.75 in., $E = 0.75$ in. min. Standard legend lights ($F = 1.50$ in., $G = 0.50$ in.,) are preferred.

Covers should be hinged to allow ready access to lamps.

Press-to-test features are desirable to check burned-out indicator lamp.

ing labels where they will do the most good for the operator who has to read them.

4. When identification marks are put on individual parts to aid assembly, use the flattest, most uncluttered surface. But place them where they will not be accidentally scraped off or obscured during or after assembly.

5. Labels can be put in the center of dials and scales if other information (trademarks, manufacturer's data) does not crowd or distract.

6. Group functionally related controls and indicators together—under one general heading, if possible. Controls requiring sequential operation should be grouped and spatially organized for maximum simplicity. Labeling can be improved by enclosing each related group with a black demarcation line and color-coding the enclosed area. Width of the line should correspond with importance of function involved: narrow ($\frac{1}{32}$ in.) for groups of secondary importance; wide ($\frac{1}{16}$ in.) for critical groups. Red demarcation lines can enclose "emergency" groups.

7. Wherever possible, arrange switch positions on selector switches in a semicircle above the switch.

EDITOR'S NOTE: Though proper labeling helps the operator make quick decisions other factors of panel design will also save time, avoid errors and give more operator efficiency. For example, knobs for selector switches will be most readable and most easily positioned if they are of functional shape—see "Choosing Selector-switch Knobs," Dec 8 '58, p 103. Poorly designed instrument dials are another potential source of confusion and errors. "Obtaining Readability in Instrument Dials," Apr '50, p 109, discusses reading errors, scale numbering, and zero-point location. And "9 Ways to Make Instruments Readable," Feb 3 '58, p. 61, points to troublemakers (poor illumination, illegible numerals, confusing scales, parallax) and suggests ways to avoid them.

The most efficient arrangement of instruments and controls on consoles has also been studied by human-factors researchers. Recommendations based on this research will be found in "Designing Control Consoles," Apr 13 '59, p 64. "Designing the Products to Suit Human Dimensions," Sept '55, p 167, gives average anthropometric dimensions—they help the designer keep controls within the reach of operators, and instruments within the range of vision.

See also the book, *Designing for People*, by Henry Dreyfus; Simon and Shuster, 1955.

ALLOYED PLASTICS

GIVE OILLESS BEARINGS

Under development for four years, a completely new oilless bearing material has appeared with high load capacity and low coefficient of friction. Here are tables and curves that compare these bearings with other sliding types.

H CLAY MELLOR, chief engineer
Arguto Oilless Bearing Co, Philadelphia

A new type of impregnated-plastic bearing has been developed by Arguto which can operate for prolonged periods at fairly high loads or temperatures—and without need for lubrication. Tests have shown that the "MP" bearings have a *PV* value of 50,000 and a friction coefficient under 0.1.

The bearing material is an alloy of several plastics blended with both synthetic dry and viscous lubricants. The bearings will develop a boundary film at a wide range of speeds. But they also give good wear protection at speeds too low to develop a boundary-film condition.

The PV Factor

A common yardstick of sliding bearings (whose motion is a sliding of one surface over the other, in contrast to ball, roller or needle bearings that use rolling elements) is the *PV* factor. The factor gives the relationship between load-carrying capacity of the bearing and journal velocity. Here P is the unit load, lb/in², of the projected area of the bearing and V is the surface velocity of the journal, ft/min. Therefore:

$$PV = \left(\frac{W}{dL}\right)\left(\frac{\pi\, dn}{12}\right)$$

or

$$PV = \frac{\pi\, Wn}{12L}$$

where W = total load, lb
d = journal dia, in.
L = bearing length, in.
n = journal speed, rpm

Here is how to use the *PV* formula. The *PV* factor has been determined by tests by the manufacturer. Usually the bearing load and the speed are fixed by other requirements. The journal diameter does not appear in the final equation. This leaves *L* or *PV* as the only variables. Thus, if a bearing with a *PV* value of 30,000 and shaft speed of 1500 rpm must carry a load of 100 lb, the required bearing length is

$$L = \frac{\pi(100)(1500)}{12(30{,}000)} = 1.31 \text{ in.}$$

If this length is too large, a bearing must be found with a higher *PV* value.

Complex Composition

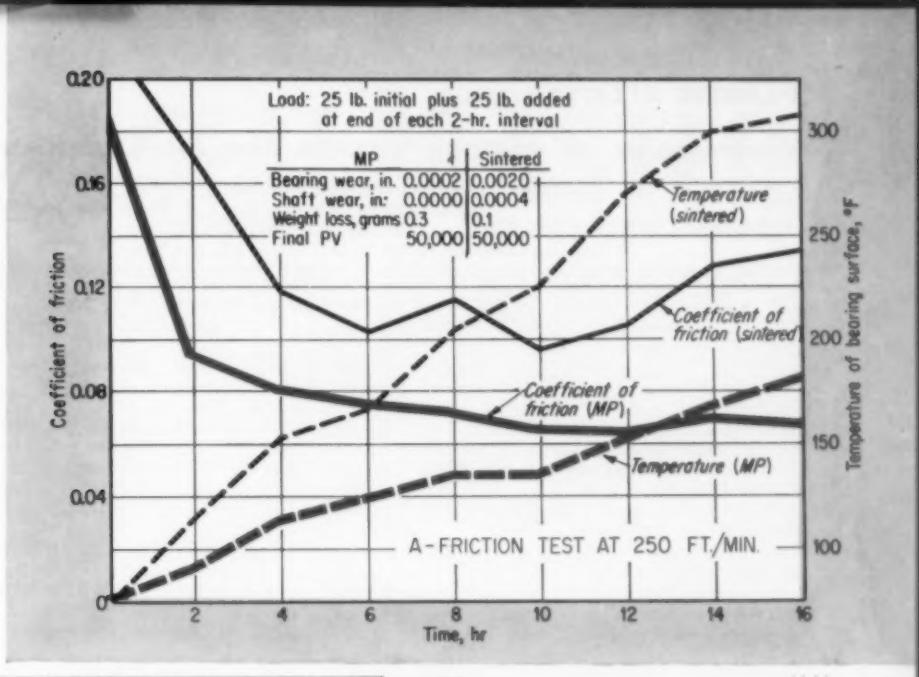
Each ingredient blended into the alloy of plastics is added to perform a particular bearing function or to supplement a physical property of another ingredient. Thus final performance of the bearing is closely controlled and its over-all characteristics are superior to those obtainable from any single material. Final result is a bearing with a wide ambient-temperature range, a low coefficient of friction, high load-carrying capacity, good heat conductivity, low thermal expansion, low temperature-rise, low water absorption, good resistance to corrosion and abrasion. It needs no lubrication. Unlike many plastics it won't cold-flow or melt.

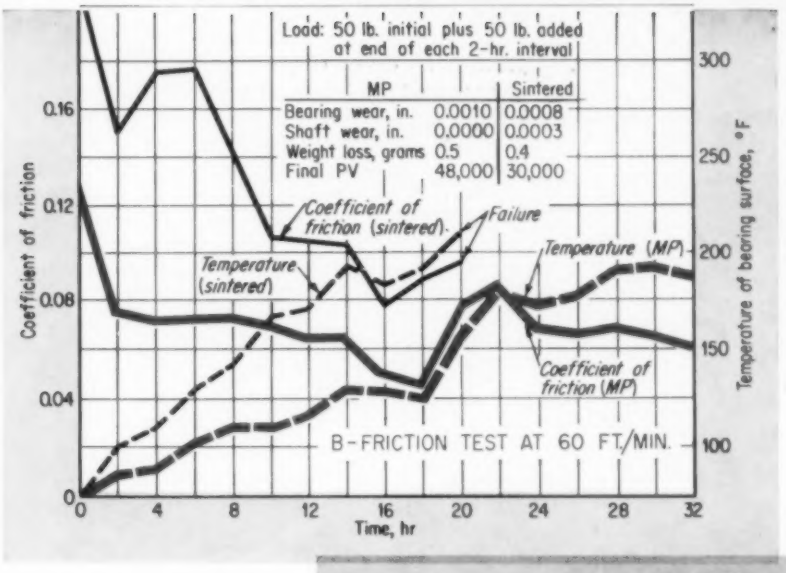
One of the plastics in the composition acts as reservoir for the synthetic viscous lubricants and, when warmed, meters lubrication to the bearing surface. When rotation ceases and the bearing cools, the lubricant is reabsorbed and stored until journal rotation again warms the bearing. Almost 20% of the bearing volume is made up of viscous lubrication.

A second plastic is added to increase the thermal conductivity of the bearing material so that heat generated at the surface is dissipated through the wall to the bearing housing. The excellent heat dissipation, combined with the low coefficient of friction, permits MP bearings to reach a thermal balance at a lower temperature than is possible with other types of oilless bearings.

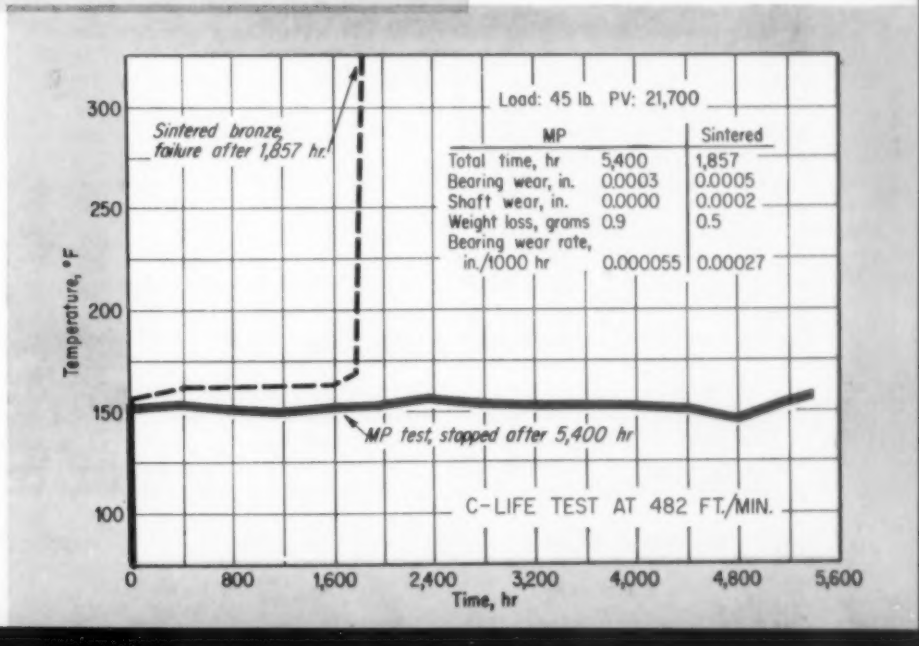
The synthetic lubricants in the bear-

TEXT CONTINUED ON PAGE 60


Load: 25 lb. initial plus 25 lb. added at end of each 2-hr. interval
MP | Sintered
Bearing wear, in. 0.0002 | 0.0020
Shaft wear, in. 0.0000 | 0.0004
Weight loss, grams 0.3 | 0.1
Final PV 50,000 | 50,000
Temperature (sintered)
Coefficient of friction (sintered)
Coefficient of friction (MP)
Temperature (MP)
A-FRICTION TEST AT 250 FT./MIN.
Coefficient of friction
Temperature of bearing surface, °F
Time, hr


Load: 50 lb. initial plus 50 lb. added at end of each 2-hr. interval
MP | Sintered
Bearing wear, in. 0.0010 | 0.0008
Shaft wear, in. 0.0000 | 0.0003
Weight loss, grams 0.5 | 0.4
Final PV 48,000 | 30,000
Coefficient of friction (sintered)
Failure
Temperature (sintered)
Temperature (MP)
Coefficient of friction (MP)
B-FRICTION TEST AT 60 FT./MIN.
Coefficient of friction
Temperature of bearing surface, °F
Time, hr

3 TESTS COMPARE "MP" AND SINTERED-BRONZE BEARINGS


Load: 45 lb. PV: 21,700
Sintered bronze, failure after 1,857 hr.
MP | Sintered
Total time, hr 5,400 | 1,857
Bearing wear, in. 0.0003 | 0.0005
Shaft wear, in. 0.0000 | 0.0002
Weight loss, grams 0.9 | 0.5
Bearing wear rate, in./1000 hr 0.000055 | 0.00027
MP test, stopped after 5,400 hr
C-LIFE TEST AT 482 FT./MIN.
Temperature, °F
Time, hr

COMPARISON OF VARIOUS OILLESS AND DRY-LUBRICANT BEARING MATERIALS

Conditions: Speed — 350 ft/min. (1340 rpm)
Load — 25-psi initial load plus 25 lb added after each 2-hour interval
150-psi maximum load
Bearing Dimensions — 1½ in. OD; 1-in. length; 1-in. bore

Bearing Material	Coef. of Friction		Temperature, °F		Wear		Average Wear Rate, in./hr	PV Final	Failure Time to:
	Average	Final	Average	Final	Bearing	Shaft			
NYLON (molded & annealed)	0.315	Frozen	203	320	Melted	0.0000	.....	8,750	:10
ACETAL RESIN (machined from bar)	0.357	Frozen	205	340	Melted	0.0000	.....	8,750	:13
NYLON-LINED (molded in steel shell)	0.332	Frozen	170	320	Melted	0.0000	.....	8,750	1:35
CARBON GRAPHITE	0.295	0.535	237	600	0.0010	0.0005	0.00025	26,250	4:15
ARGUTO-K (impregnated wood)	0.119	0.184	101	145	0.0000	0.0000	0.00000	26,250	5:15
SINTERED NYLON (graphite filler, oil-impregnated)	0.271	0.284	233	325	0.0025	0.0000	0.00040	30,000	6:30
SINTERED BRONZE (oil-impregnated)	0.170	0.270	228	545	0.0022	0.0004	0.00020	43,750	10:05
TEFLON (woven bonded to phenolic shell)	0.210	0.137	221	268	0.0049	0.0000	0.00041	52,500	Finished Test (12 hr)
ARGUTO-MP (molded plastic)	0.093	0.080	122	202	0.0011	0.0000	0.00010	52,500	Finished Test (12 hr)

PHYSICAL PROPERTIES OF MP BEARINGS

Compressive Properties	
Compressive Strength	8375 lb/in.^{2}
Compressive Failure	4.77%
Elastic Modulus	4.97×10^4 lb/in.^{2}
Tensile Properties	
Tensile Strength	2810 lb/in.^{2}
Elongation	0.6%
Flexure Properties	
Flexure Strength	4285 lb/in.^{2}
Water Absorption	0.73%
Coefficient of Thermal Expansion	2.53×10^{-5} in./in./°F
Rockwell Hardness	L54
Impact Resistance, Izod	0.6 ft-lb/in. notch
Temperature Range	−270 to 375 F
PV Factor	30,000 psi-ft/min
Coefficient of Friction	0.025 to 0.120

ing are blended with an inhibitor to permit operation at 375 F without oxidation affecting the lubrication properties. A thermosetting resin holds the masses together and develops good compressive strength (see table of properties above).

The MP bearings are generally produced by compressive molding; therefore any shape that can be obtained from a mold is possible. The bearings are also readily machinable—oil-flow properties are not affected—and the bearing material can be purchased in the form of rods for machining.

Test Program

To test out the bearings, a new machine was developed (*PE*—Apr 20, p 25) which accurately measures the frictional resistance and bearing-surface temperature of a bearing. The machine employs strain gages and an oscillograph to measure the friction force; bearing temperature is measured by means of a thermocouple buried in the bearing wall within 0.020 in. of the loaded side of the bearing surface. Shaft speed is indicated directly on a tachometer.

The bearings were tested in the laboratory for over one hundred thousand hours and have been field-tested in a wide variety of bearing applications. The upper table on this page shows the result of a typical comparative test made with various other oilless and dry bearing materials.

In tests with loads ranging from 10 psi to 1000 psi and speeds from 50 to 1000 ft/min., the MP bearings carried a higher load and developed less frictional resistance than sintered bronze. Curves A and B on previous page show results of two such tests.

Additional comparative tests show that the material has a longer life and will carry higher speeds and loads than is possible with sintered bronze. In a life test (see Curve C) on a 1-in.-dia shaft turning at 1850 rpm, a sintered-bronze bearing carrying a load of 45 lb (PV = 21,700) failed after 1857 hours. An MP bearing under identical conditions was operated satisfactorily for 5400 hours.

EDITOR'S NOTE: A new polyamide, nylon-11, is also showing itself to have a bright future as a cladding for metal sleeve bearings. This plastic offers a bearing surface that will take high load, needs no lubrication and will stand up to moisture better than other nylons can. Additional advantages come from the way it is applied to metal by the fluidized powder techniques. Already bearings clad with nylon-11 are in the developmental use in farm machinery and auto steering ball joints. For details see "Nylon-Clad Sleeve Bearings," Mar 3 '58, p 52.

Sintered nylons now can be fortified several ways, with graphite or molybdenum additives. Result is stronger parts with moisture resistance that improves dimensional control and permits higher loads without deforming. Details can be found in "Additives Put Muscle Into Sintered Nylon Parts", Sept 15 '58, p 86.

NEW *from* SEALMASTER®

ECONOMY
PERFORMANCE
QUALITY
LFT 2-BOLT FLANGE UNIT
LF 3-BOLT FLANGE UNIT
REVERSIBLE FOR FLUSH OR RECESSED MOUNTING
Precision self-aligning one-piece unit. No extra assembly costs for you.
Malleable housing provides maximum strength with lightweight.
Permanently sealed — prelubricated with high grade lubricant.
Nothing of comparable value in low price field.
Reversible for flush or recessed mounting.
FLUSH MOUNTING
RECESSED MOUNTING
AVAILABLE IN A COMPLETE SERIES
LF PILLOW BLOCK
L BEARING
S BEARING
LFT FLANGE UNIT
LF FLANGE UNIT
Available in shaft sizes ¾" thru 1 7/16"

SEALMASTER BEARINGS

A Division of STEPHENS-ADAMSON MFG. CO.

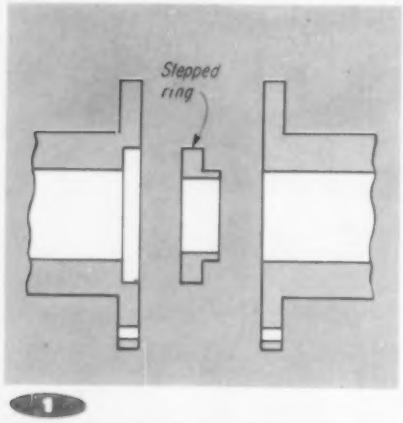
9 RIDGEWAY AVE. • AURORA, ILL.

Write for Bulletin 359

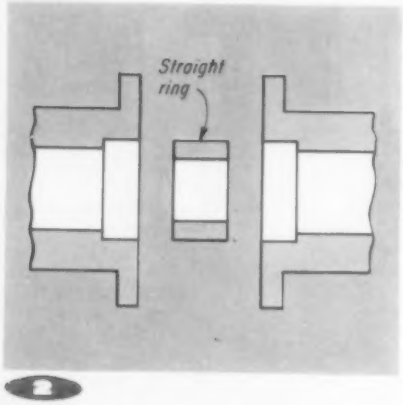
How to ALIGN

Here are 9 more ways supplementing those that appeared in the last Design issue.

FRANK WILLIAM WOOD JR, *Vitro Labs, Silver Spring, Md*
JOHN F MINTER, *Citizens Rapid Transit, Hampton, Va*

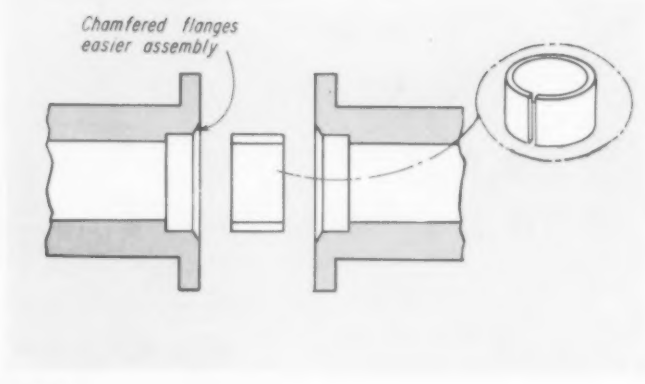


1



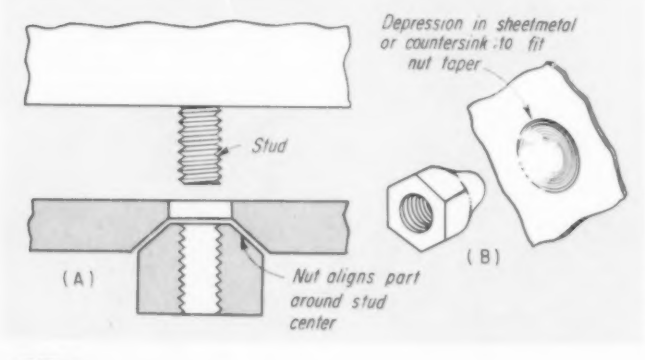
2

Alignment rings . . .
provide accurate axial alignment, may be either stepped (1) or straight (2). Additional means must be provided if accurate radial alignment is also desired.



3

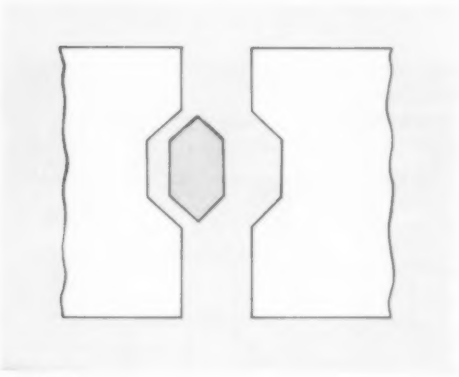
Split spring-sleeve . . .
is somewhat similar to a straight ring, but has advantages where high-precision alignment is unnecessary: It doesn't require close tolerance to insure a tight mating fit; it is self-retaining in one section while the other is being aligned—a helpful feature when working in close quarters.



4

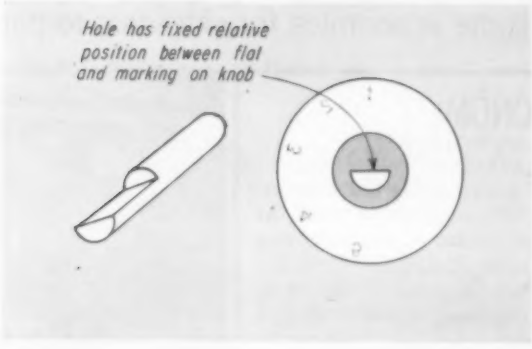
Beveled nut . . .
offers extra benefits besides alignment. On an automobile wheel, for example, it provides locking without need for lock washers or special locknuts. In (A) it can also help draw heavy plates into alignment.

MATING PARTS



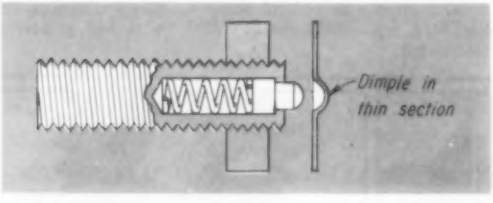
5

Hexagonal bar or ring . . .
aligns heavy equipment where it would be difficult to guide the mating sections into position. The bevels provide gradual alignment as the sections come together.



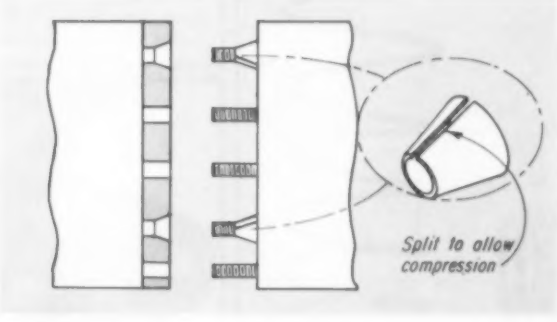
6

Flatted shafts . . .
insure, for example, the relative location of knob markings, the flat on a shaft and the internal position of a switch. These relations are fixed during design; regardless of how many times the knob is removed, alignment will always be correct when the knob is replaced.



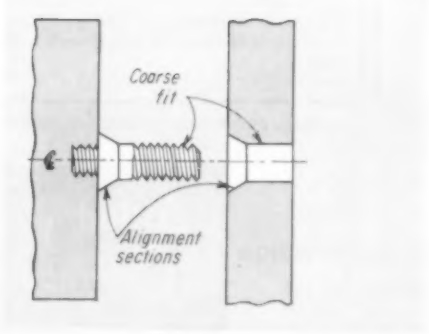
7

Spring-loaded pins . . .
are commercially available, and useful where component parts are delicate or have a relatively thin section in one of the mating units.



8

Split taper-plugs . . .
provide accurate alignment of mating sections without requiring close tolerances between bolts and holes. For example, a pair of flanges may have many loose-fitting bolts—but with two tapered plugs over only two of the bolts, there will be self-alignment as their nuts are tightened.



9

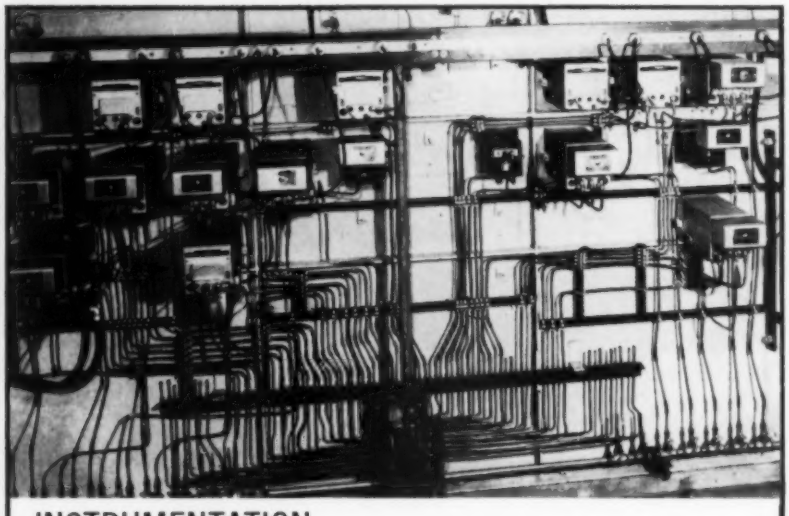
Alignment section . . .
on loose-fitting stud works similarly to tapered plugs. All tapers should be kept free from hard dirt-particles, which can cause eccentricity *(PE—Sep 1 '58, p 48.)*

Plaskon Nylon News

A round-up of recent happenings in type-6 nylon, including new applications... and some economics for extruders to ponder.

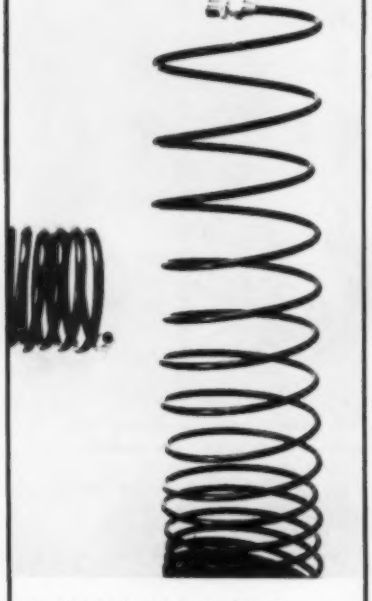
ECONOMY IN EXTRUSIONS

The question, "Is the scrap reusable?" can make or break the profit picture of any extruding operation. PLASKON Nylon Extrusion Compound 8205 maintains high-melt viscosity through successive regrinds. Scrap can be re-extruded several times without loss of basic properties. This scrap re-use often gives a sharp competitive advantage to users of PLASKON 8205.



INSTRUMENTATION

Color-coded nylon tubing replaces copper in control panel at Allied Chemical's phthalonitrile plant, Edgewater, N. J. Nylon's advantages: 50% less in cost, greater corrosion resistance, easily color-coded.

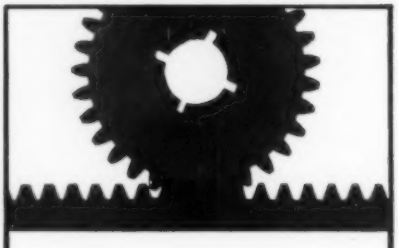


TOUGH AIR HOSE

For use with pneumatic tools, this lightweight "Nycoil" hose is extruded from PLASKON Nylon. It's tough, heat-resistant, unaffected by hydrocarbons . . . has permanent recoil action.

FOOTBALL CLEATS

Molded of PLASKON Nylon, these cleats outwear other types by a factor of 5 to 10. Their safety and durability suggest other possible applications in sports equipment.



GEAR AND RACK

Type-6 nylon has higher impact resistance than other nylons. This advantage goes to work in a gear and rack molded of PLASKON Nylon and used in Scott Company lawnmowers. The parts are more durable than the metal ones they replace.

For further information, or technical assistance, write to our Nylon Product Development Department.

PLASTICS AND COAL CHEMICALS DIVISION
40 Rector Street, New York 6, N. Y.

Allied Chemical

For Thick-end Cylinders

—*these stress-correction factors*

Formulas and examples show how correct maximum stresses can quickly be found.

ROBERT I ISAKOWER
Ordnance engineer, Picatinny Arsenal

What effect does a thick end have on stresses in a thin circular cylinder? It's important to know because the stresses may be more than quadrupled in some cases. For example, proceed with caution whenever a thick flange supports a tensile-loaded cylinder—stresses at the flanged end will usually be increased. Moreover, the restraint imposed by the fixed end invites bending as well as direct membrane stresses. This changes the stress pattern. A thick end-closure for a pressure vessel has the same effect.

Formulas:

1. Cylinders with internal pressure
(Add δ for inner fiber; subtract for outer)

$$S_A = (PR/2h)\,(1 \pm \delta_1)$$

$$S_H = (PR/h)\,(1 - \delta_4 \pm \delta_3)$$

2. Cylinders with tensile load only
(Subtract δ for inner fiber; add for outer)

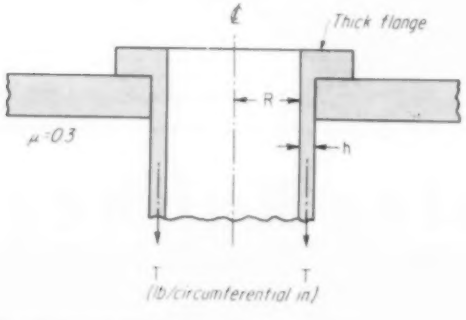
$$S_A = (T/h)\,(1 \mp \delta_2)$$

$$S_H = (\mu T/h)\,(1 + \delta_5 \mp \delta_2)$$

Correction factors (δ) for various values of Poisson's ratio are charted on the continuing page (excepting δ_5, which equals 1 for all values of μ).

SAMPLE PROBLEMS

1. A tensile-loaded cylinder has $R = 12$ in., $h = 0.4$ in., $T = 1000$ lb/in., Poisson's ratio $= 0.30$. Find max stresses at flange end. (See sketch below.)



SYMBOLS

h = cylinder-wall thickness, in.
P = internal pressure, psi
R = mean cylinder-radius, in.
S_A = max axial stress, psi
S_H = max hoop stress, psi
T = tensile load, lb/in. (=PR/2 when cylinder is loaded with internal pressure.)
δ = correction factor
μ = Poisson's ratio

For accurate results R/h should be not less than 10.0 approx.

The Solution:

From chart, $\delta_5 = 0.545$; formula for case 2 gives

$$S_A = \frac{1000}{0.4}\,(1 + 0.545)$$

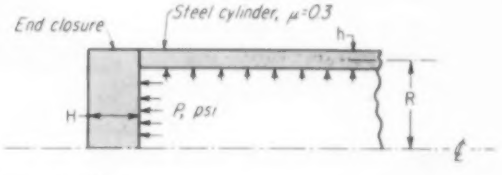
$$= 2500 \times 1.545$$
$$= 3860 \text{ psi}$$

$$S_H = 0.3\left(\frac{1000}{0.4}\right)(2 + 0.545)$$

$$= 750 \times 2.545$$
$$= 1905 \text{ psi (outer fiber)}$$

Both stresses have been increased; without correction factors, axial and hoop stresses are respectively 2500 and 750 psi. (These are the stresses that exist in the tube where the bending effect is damped out.)

2. A pressure vessel has $R = 10$ in., $h = 0.3$ in., $H = 2.0$ in., $P = 500$ psi, $\mu = 0.3$.
Find max stresses at closed end.

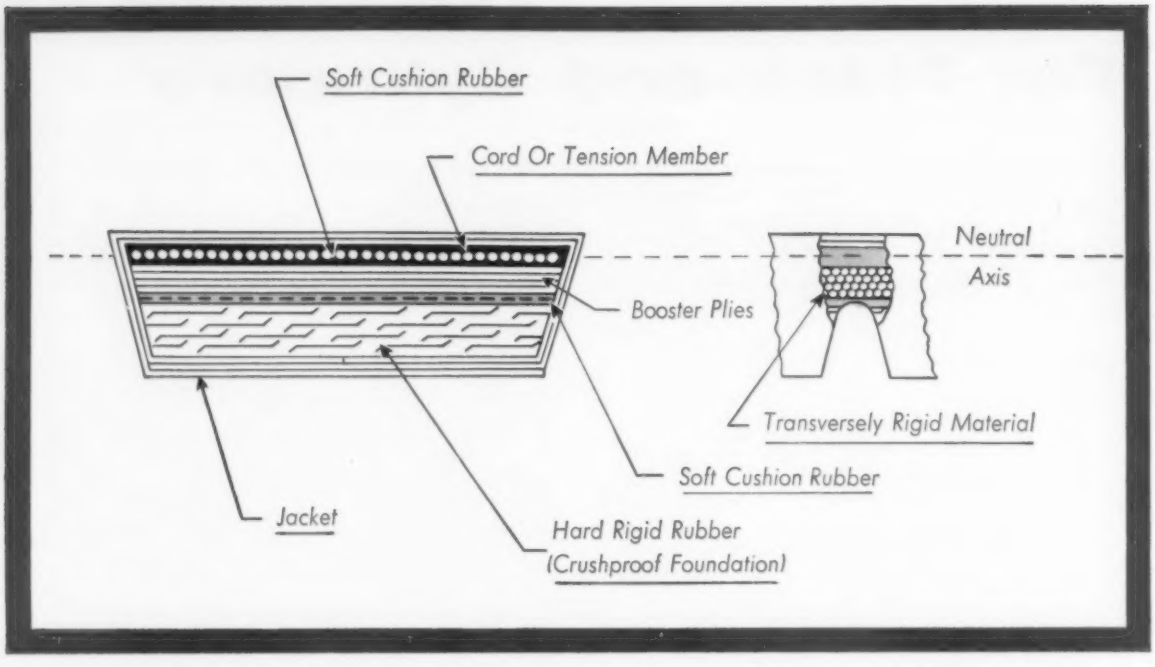


The Solution:

Since H is large compared to h, the flat plate may be considered infinitely rigid compared to the thin cylinder. It is therefore valid to assume the condition

(CONTINUED ON PAGE 67)

ROYAL VARIABLE SPEED BELT



HERE'S WHY THIS VARIABLE BELT IS NON-SQUASH, NON-SAG

No excuse for any more variable speed belt problems. The U. S. Royal Variable Speed Belt will lick any production problem – where other belts try and fail.

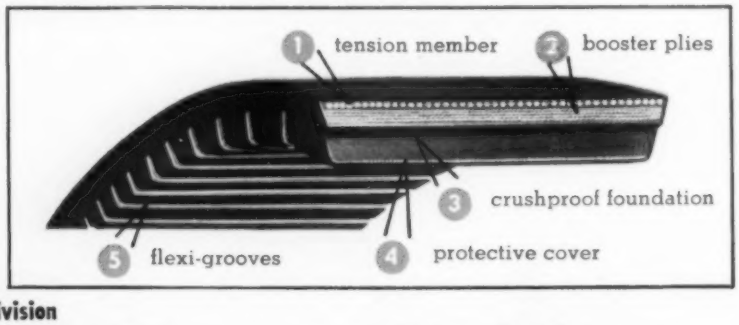
Note in the diagram the use of hard rigid rubber – the soft cushioning rubber in which cords or tension members are imbedded – the special jacket (oil and heat resistant).

The exclusive and complete crosswise rigidity in U. S. Royal prevents squashing. Lengthwise stretch is just about zero, by every test. *No sagging.*

U. S. Royal has complete accuracy regardless of speed changes – whether you switch from 2000 rpm to 10. It has scored a complete success in every textile mill, pulp and paper mill, chemical plant and metal working plant in which it has been installed.

• • •

Your nearest "U.S." Power Transmission Distributor will be glad to demonstrate the U. S. Royal on your own drives, at your own plant. You'll save a great deal in replacement costs and down goes downtime.



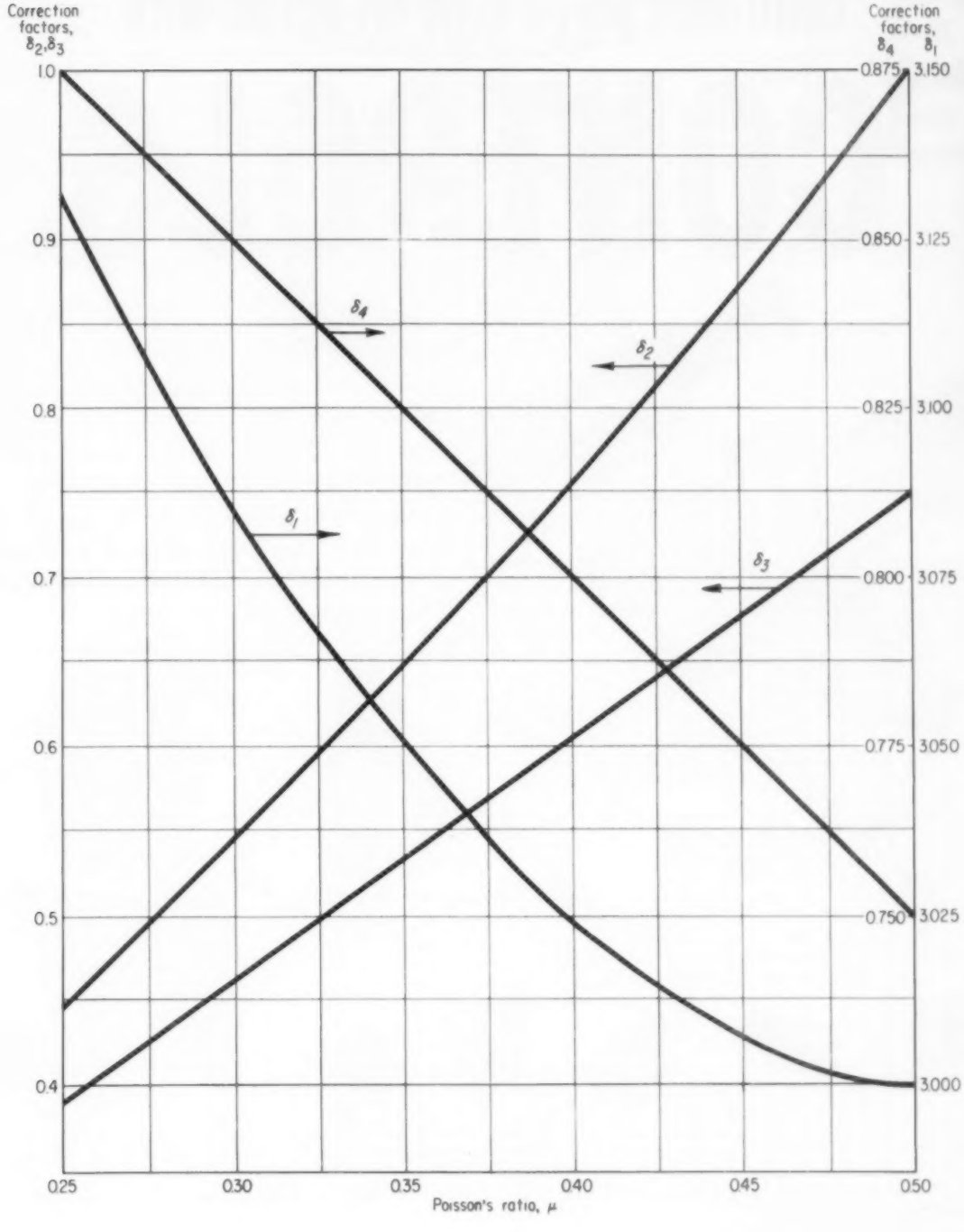
Mechanical Goods Division

United States Rubber

WORLD'S LARGEST MANUFACTURER OF INDUSTRIAL RUBBER PRODUCTS

Rockefeller Center, New York 20, N.Y. In Canada: Dominion Rubber Company, Ltd.

Thick-end cylinders (cont.)



here is that of a fixed-end cylinder.

From the chart, $\delta_1 = 3.086$, $\delta_4 = 0.850$, $\delta_3 = 0.4625$

Formula for case 1 gives

$$S_A = \frac{500 \times 10}{2 \times 0.3}(1 + 3.086)$$

$$= 8330 \times 4.086$$

$$= 34{,}100 \text{ psi (inner fiber)}$$

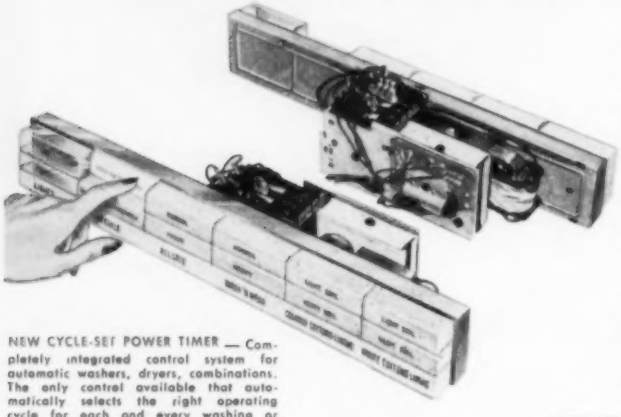
$$S_H = 16{,}660 \times 0.6125$$

$$= 10{,}200 \text{ psi (inner fiber)}$$

In this case, axial stress is increased while hoop stress is decreased owing to the local bending.

Every appliance made today can be controlled just a little bit better with...

CC CONTROLS



NEW CYCLE-SET POWER TIMER — Completely integrated control system for automatic washers, dryers, combinations. The only control available that automatically selects the right operating cycle for each and every washing or drying situation.

Individual components or completely integrated systems. Whichever you choose, you can be sure of this: Controls Company products are function-mated to the appliances they control. Field records show this results in extra value that helps sell the end-product . . . *and keep it sold!*

Shown here are some of the CC controls now helping to make many appliance lines just a little bit better than competition. Write for facts about these and other CC controls.

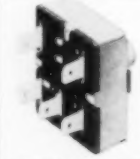
LATERAL TIMERS — Just 2-17/32" deep. For washers, dryers, combinations dishwashers, other automatic equipment.

TANDEM TIMERS — Drive mechanism to rear of switch case for "tight-squeeze" installation in automatic equipment.

SOLENOIDS — Exclusive double T plunger means more pull for more applications. Four types, twelve models.

SNAPAC SWITCHES —750 Series (shown) for limit, safety inter-locking, door and control switch needs.

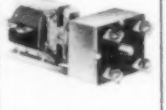
PRESSURE SWITCHES —Single and multi-level pressure. Designed to control liquid levels.



ROTARY SWITCHES — Compact 777 Series (shown) ideal for appliances, vending machines.

SYNCHRONOUS MOTORS—offer eleven speeds, three shaft types, two lube systems.

INTERVAL TIMERS —Type 105 (shown) for preset appliance time control.



SOLENOID OPERATED SWITCHES — Type 12270 makes, breaks two circuits simultaneously.

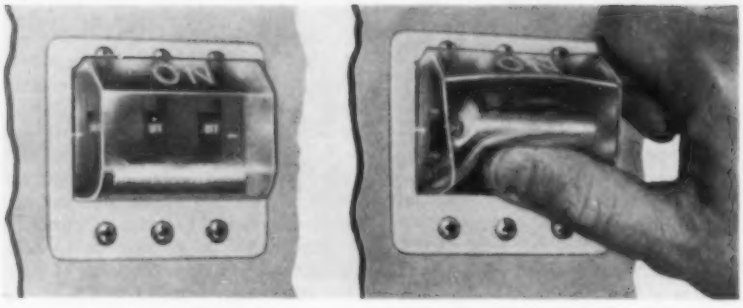
Creative Controls for Industry

CONTROLS COMPANY OF AMERICA

9563 Soreng Avenue • SCHILLER PARK, ILL.

COOKSVILLE, Ontario • NIJMEGEN, Holland

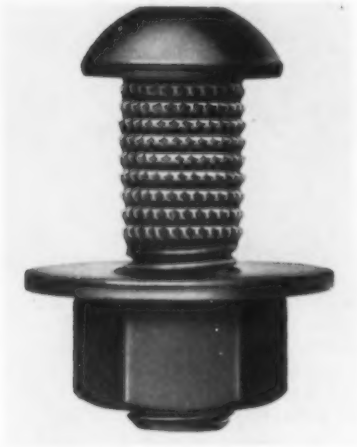
SIGNIFICANT COMPONENTS MATERIALS PROCESSES



Flexible silicone covers . . .

can be molded as windows, lenses or transparent bellows to cover switches, control panels and other moving parts. Glass-clear silicone is said to have elongation of 500% and temperature range of —160 to 500 F; to be resistant to acids, ozone and sunlight, and to have a shelf life in excess of 25 yr. Visual inspections and mechanical adjustments can be made on hot or cold mechanical and electrical devices without exposing controls or removing cover. For example, as illustrated, units can be actuated through cover. **APM Corp, Rubrglas Dept, 252 Hawthorne Ave, Yonkers, NY.**

Circle 1, Reader Service Card



Knurled-shank bearing bolt . . .

is said to surpass other structural bolts in shear strength and resistance to slip. Button-head shape provides equivalent bearing area of comparable hex-head high-strength bolt plus a washer. Knurls, set on spiral that reduces driving load, give body-bound fit when bolt is driven or pulled into place—no head washers necessary. Body length is determined by thickness of members to be joined. Made of heat-treated high carbon steel meeting ASTM A-325 specifications. Can be assembled wherever conventional high-strength bolt can be used in punched or drilled holes. With nut and washer, bolts are said to cost the same, size for size, as Dardelet rivet-bolt with nut and hex-head high-strength bolt with nut and two washers. **Lamson & Sessions Co, 5000 Tiedeman Rd, Cleveland 9.**

Circle 2, Reader Service Card

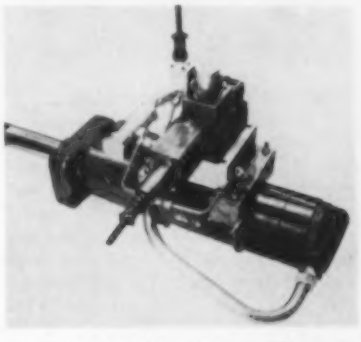
Columbium-base alloys . . .

are the first of a high-temperature series to be made commercially available. Columbium-tantalum-zirconium and columbium-zirconium alloys have melting points of 4550 and 4350 F, respectively, and permit fabrication at room temperature, in as-worked or annealed state. Both can be welded with ductile welds and have little or no tendency to fracture in heat-affected zones. Ductile to brittle transition temperatures in annealed state are well below room temperature. First-mentioned alloy has high resistance to oxidation compared with pure refractory metals. Moreover, oxide film is said to form a lasting protective coating. In air, alloy has ultimate tensile strength of about 30,000 psi at 2000 F; about 12,000 psi at 2400 F. 10-hr stress-to-rupture strength at 2000 F is said to be 26,000 psi. Second alloy has comparable properties, with higher strength-weight ratio. Oxidation resistance is comparable to pure columbium. Now made in 4-in.-dia ingots, alloys are available in various mill forms and fabricated parts. Prices range from $75 to $90 per lb in sheet and plate form. Delivery, 8 to 10 wk. **Fansteel Metallurgical Corp, North Chicago, Ill.**

Circle 3, Reader Service Card

High-speed positioning systems . . .

capable of speeds of 8 fps on a 4-in. bore cylinder, with accuracy of better than 1 part in 2000, are offered in a range of 1 to 500 hp. Equipped with electrohydraulic actuators that can operate at



pressures to 3000 psi max. Frequency response is flat up to 19 cps in large-capacity systems, up to 50 cps in smaller systems. High speed and accuracy make systems suitable for heavy-duty applications in aircraft, rocket and nuclear fields. Systems cost $5000 to $10,000 per loop. 5-mo delivery. **CompuDyne Corp, 792 S Warminster Rd, Hatboro, Penna.**

Circle 4, Reader Service Card

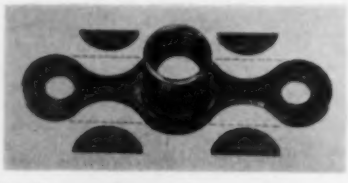
Nylon-like gum plastic . . .

based on acrylonitrile-butadiene-syrene-formulation has excellent creep resistance at temperatures to 160 F, low moisture absorption and excellent chemical resistance. Elastic modulus of 450,000 psi is said to be highest of impact thermoplastics. Designated Kralastic-MM, polymer can be molded by conventional processes, with shrinkage as low as 0.4%. Impact strength is 1.5-ft-lb in. Currently priced at 50¢ per lb. **Naugatuck Chemical Div, US Rubber Co, Naugatuck, Conn.**

Circle 5, Reader Service Card

Conductive heating tape . . . transmits electricity without wires and is said to maintain uniform surface temperature. Tape, made of woven glass fibers impregnated with conductive silicone rubber, is flexible and can be cut to any length. Initially offered in widths of ½ to 6 in. and thicknesses of 0.005 to 0.012 in. in any desired length. Tape can be produced to meet physical and resistance value requirements of quantity users. Said to cost less than existing types of metallic heating units, with tests indicating the tape withstands continuous temperatures to 400 F and temperatures of 600 F max for short periods. Silicone rubber also prevents tape from becoming brittle at very low temperatures. **Sunelec Inc, PO Box 1139, Trenton, NJ.**

Circle 6, Reader Service Card



Lightweight anchor nuts . . . are said to reduce weight an average of 23% while meeting applicable national aircraft standards. Balanced design is achieved by removal of excess metal without sacrifice in full performance. Anchor nuts comply with all industrial and military specifications. Line covers single lug, two lug and corner types. Five sizes, 4-40 through ¼-28, are available. **Voi-Shan Mfg Co, 8463 Higuera St, Culver City, Calif.**

Circle 7, Reader Service Card

Low-torque dial counter . . . is for use as a position indicator for servo systems with constant torque over entire range. Includes two concentric pointers and large bold index marks and numbers on a white face. Red sweep pointer is connected directly to input shaft and coarse pointer is back-geared to input shaft, at 10:1 for analog or 36:1 for angle function applications. Large sweep pointer traverses approximate 9½ in. scale, making unit directly readable to 0.00 and by interpolation to 0.0000. Semiflush bezel allows front-of-panel mounting. Bezel has 9⅞ in. OD and max protrusion of ⅞ in. **D S Plumb Co Inc, Dept IEN, 77 Norfolk St, Newark 3, NJ.**

Circle 8, Reader Service Card

High-pressure regulator . . . for use with inlet pressures of 100 to 3000 psi controls outlet pressure to within 0.5 psi over entire range. Regulators are normally closed, eliminating shock loading on downstream system when inlet system is suddenly activated. Operates in ambient temperatures and with air-supply temperatures of —100 to 300 F. Air-flow capacity ranges from 0.5 to 100 scfm, with air flow dependent upon regulated pressure and supply pressure. Regulated pressure settings range from 10 to 200 psi. Regulators are available with internal pressure sensors, remote pressure sensors, and with a miniature, integral solenoid valve to provide shutoff as well as regulation. Weighs 1.25 lb. Originally designed and developed for missiles, regulator is now available for commercial systems utilizing high-pressure source. Compatible with most gases currently used in the aircraft and missile fields. **Aerodyne Controls Corp, 1783 New York Ave, Huntington Station, NY.**

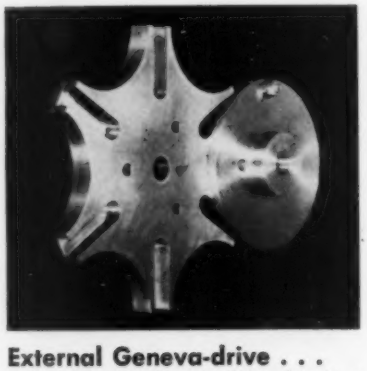
Circle 9, Reader Service Card

Heat-dissipating coil . . . that clamps around housing of operating rotary components, increases upper temperature limits of such units as servomotors and synchros. Deeply threaded or finned, the short aluminum tube, with ID slightly less than OD of component housing, is slotted lengthwise to permit insertion of spreader bar, which springs coil wide enough to insert heat-generating component. When unit is positioned properly, spreader bar is removed, allowing spring tension to act as clamp. Unit is now in contact with smooth internal coil surface, a heat-conducting element that absorbs generated heat and conducts it to fin edges for rapid dissipation. Made in sizes to fit standard size 8, 10, 11, 15 and 18 components. Coils are said to be low in cost. **Kearfott Co Inc, 1500 Main Ave, Clifton, NJ.**

Circle 10, Reader Service Card

Switch for use in 800 F . . . max ambient temperature is said to maintain operating characteristics during continuous exposure. Switch assembly is composed entirely of inorganic materials and is enclosed within ceramic base to withstand shock to 100 g and vibration of 20 g in frequencies of 25 to 2000 cps. Switching element is one-piece sine blade that eliminates knife edges and high friction points. Leaf-spring actuator is rigidly fixed, said to improve operating characteristics and reduce wear. Operating force ranges from 0.5 to 1.5 lb. Release force is 0.2 lb min. Rated 5 amp, 30 v dc, resistive. Life expectancy is said to be over 25,000 cycles with 5 amp, resistive, on both contacts at 800 F. Weight is approximately 1 oz. **Metals & Controls Div, Texas Instruments Inc, Attleboro, Mass.**

Circle 11, Reader Service Card



External Geneva-drive . . . units convert rotary to intermittent or indexing motion. Drives are said to index at speeds up to 2000 indexes per min. Locking after each index is said to be accurate to within 1/1000 in., with smooth indexing in either direction. Available with any center distance to 24 in. and any number of indexing stations. **Geneva Motions Corp, 1114 NE Cleveland St, Clearwater, Fla.**

Circle 12, Reader Service Card

Two-speed hydraulic pump . . . is rated at 10,000 psi and combines basic components of pressure generation system into single unit. Said to be compatible with most high-pressure hydraulic systems. Powered by high-torque, repulsion-start, induction-run motor that develops 1 hp

CONTINUED ON PAGE 72

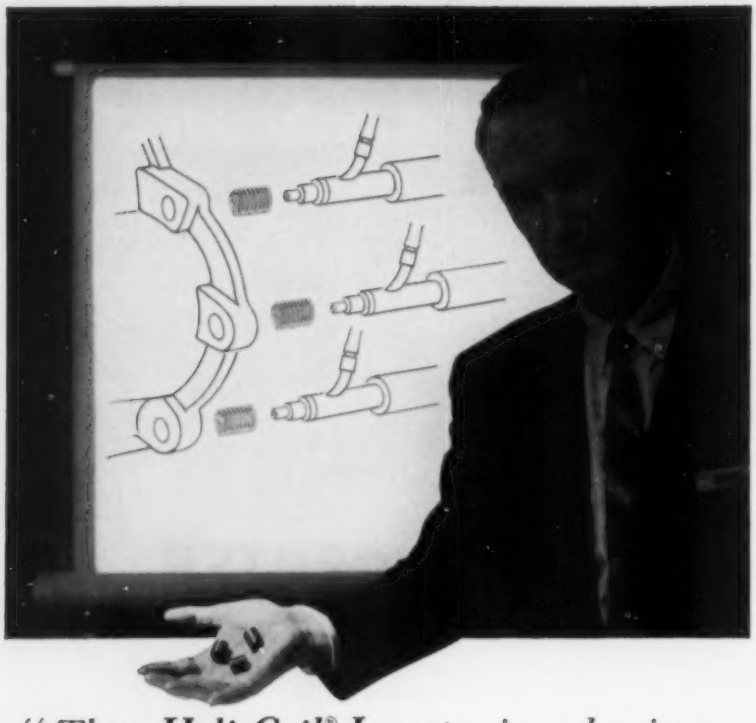
Order McLouth high quality stainless sheet and strip from your STEEL SERVICE CENTER

AMERICAN STEEL

WAREHOUSE ASS'N.

McLOUTH STEEL CORPORATION

Detroit 17, Michigan



"These Heli-Coil® Inserts give aluminum tapped holes the strength of steel threads in the new FORD transmission housing."

Threads in the starter mounting pad in the new Ford aluminum transmission housing would have been too soft to resist wear under vibration, impact and removals of the starter for service. ***Heli-Coil*** steel wire inserts eliminate this problem, are installed automatically with ***Heli-Coil*** designed equipment.

Now you can design aluminum assemblies and provide permanent internal steel threads for use with steel screws or studs. And ***Heli-Coil Corporation*** also supplies high-speed, automatic installation equipment to meet mass-production schedules economically.

Opening the door to exciting new design possibilities, *Heli-Coil* Inserts:

- hold fasteners secure under impact and vibration
- prevent thread wear, stripping, corrosion, galling and seizing
- allow repeated assembly and disassembly without loss of thread strength
- can be used in standard proportion bosses without need for redesign
- are available in a complete range of U.N.C. and U.N.F. thread sizes as well as spark plug and pipe thread series
- save assembly time, space, weight and cost
- have full industrial and military approval

HELI-COIL CORPORATION
DANBURY, CONNECTICUT

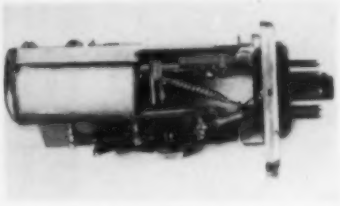
HELI-COIL CORPORATION, 605 Shelter Rock Lane, Danbury, Connecticut
I'd like more information on ***Heli-Coil*** Screw-Thread Inserts

NAME _____ TITLE _____
FIRM _____
ADDRESS _____
CITY _____ ZONE ____ STATE _____ 1582

IN CANADA: W. R. WATKINS CO., Ltd., 41 Kipling Ave., S., Toronto 18, Ont.

at 3450 rpm. Motor operates on 115 or 230 v ac, 60 cps, and may be started under full load. Motors for other standard voltages are also available. Pump, of constant-displacement type, has four axial pistons. Low-to-high pressure automatic changeover circuit provides oil delivery of 115 cu in. per min. at pressures to 150 psi, and, under load, changes oil delivery to 57 cu in. per min. at up to 10,000 psi. Price is $370. **Blackhawk Mfg Co, Dept MP, 5325 W Rogers St, Milwaukee 46.**

Circle 13, Reader Service Card



Transistor-amplified relay . . .

has power sensitivity of less than 10 microw for positive relay operation. Current sensitivity is 10 microamp at 1 v dc or an equivalent input resistance of 100,000 ohm. Other sensitivities in the relay are 25, 50 or 100 microamp at 1 v. Standard contact arrangements are SPDT or DPDT for contact loads to 3 amp at 115 v ac or 29 v dc noninductive. Bias voltage of 16 to 25-v positive dc may be supplied from an external source or from internal mercury battery. Operating life of mercury cells used in internally biased relay is rated more than 7000 hr, based on 50% usage. Said to withstand sensing currents 10 times normal operating current and temperatures of 32 to 122 F. External-biased relay mounts in can, $1\frac{5}{8} \times 1\frac{7}{8} \times 3\frac{1}{2}$ in.; internally biased relay is in can, $2\frac{5}{8} \times 2\frac{7}{8} \times 4\frac{1}{2}$ in. **General Automatic Corp, 12 Carlton Ave, Mountain View, Wayne, NJ.**

Circle 14, Reader Service Card

Monitors 3-phase systems...

with visible and audible signals for unbalanced transformer loads, grounds, single phasing and loose connections. Min and

(Continued on page 76)

MEET MRS. PETER PEFF

...and her company's new lightweight liquid-oxygen "vacuum bottle" for jet planes

Mrs. Peff, president, Superior Air Products, Newark, N. J., with Supairco's recently developed liquid-oxygen "vacuum bottle."

MANY a tough problem has been solved by Mrs. Peff and her company since 1952, when she assumed the presidency after her husband's death. Specialists in building low-temperature apparatus and complete plants to produce oxygen and other gases, "Supairco" was asked recently to develop a light, compact container to supply oxygen for aircraft crews at high altitudes.

Ingenious design utilizing the broad and varied properties available in copper and its alloys produced the "vacuum bottle" shown above. The inner sphere is of Everdur®, Anaconda copper-silicon alloy, which has the workability and resistance to corrosion needed —and, more important, the strength and toughness to make possible a relatively thin, light shell that can withstand vibration and fatigue stresses aloft—plus shocks from catapult launchings and carrier landings. The outer shell is of Anaconda copper, highly polished to reflect heat. This, plus a vacuum under .001 microns between the spheres, holds liquid oxygen at −297 F.

Starting with over 100 standard copper alloys, Anaconda can provide an almost unlimited number of combinations of useful properties. When new and unusual problems arise, use Anaconda technical specialists to help you select metals for your needs. Address the American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5041

LEFT: Inside the copper shell in main illustration is this slightly smaller liquid-oxygen container made of Everdur, the metal that spins and machines readily, is easy to join by soldering, brazing, welding. **RIGHT:** Completed liquid-oxygen converter, built by Mine Safety Appliances Company, Pittsburgh, Pa., serves 8-man crew. It is one-third the weight of the cylinder it replaces, takes much less space.

ANACONDA®

COPPER • BRASS • BRONZE
NICKEL SILVER MILL PRODUCTS
Made by The American Brass Company

Working on any of these design improvements

RELATED TO TORQUE TRANSMISSION? .... *more capacity*

If so, and if your application warrants placing the solution and ultimate cost-savings above ordinary, lower priced joint designs . . . RZEPPA can help you. Here's why:

By transmitting a uniform flow of power through ball bearing action, RZEPPA *Joints operate with less friction; carry heavier loads and are more compact than any other type of joint . . . size for size.*

RZEPPA Constant Velocity Joints are available for *light, medium* and *heavy* duty on air and space craft, vehicles and industrial machinery.

WRITE FOR LATEST LITERATURE or send your dimensional sketch with peak horsepower, R.P.M. and operating angles. Without obligation, our engineers will assist you. Address: THE GEAR GRINDING MACHINE COMPANY, Dept. PJ-559, 3901 Christopher St., Detroit 11, Michigan.

greater angles

no torsional vibration

higher speeds

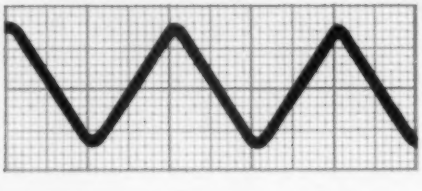
longer shaft life

extended bearing wear

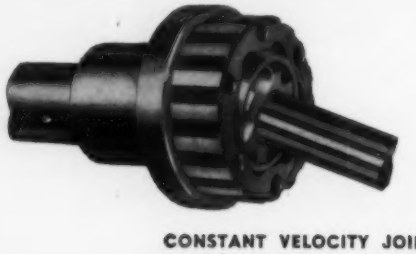
RZEPPA CONSTANT VELOCITY UNIVERSAL JOINTS

(PRONOUNCED: "SHEPPA")

Genuine RZEPPA Joints are made exclusively by THE GEAR GRINDING MACHINE CO.



ORDINARY CROSS OR PIN UNIVERSAL JOINT — Mathematics and geometry prove this joint changes velocity of the driven shaft with two high points and two low points per complete revolution. This fluctuating torque action causes vibration and wear throughout entire driving mechanism.



CONSTANT VELOCITY JOINT — This RZEPPA design joint *always* transmits smooth torque even at unbalanced angles. Such smooth torque action results from ball bearings applying power in a plane that bisects both shaft axes.

Now . . . an old company presents a new face . . . an image . . . a dynamic trademark to match the many changes that are making Titeflex the most progressive company in the flexible hose business

titeflex

titeflex incorporated springfield 4 massachusetts

PACIFIC DIVISION • SANTA MONICA, CALIFORNIA

9198

max voltage warning points can be set for each phase. Difficulty can be determined by reading three voltmeters and comparing with illustrated meter-chart on instrument face. Alarm circuit operates from independent power source of 110 v ac to 6 v dc. Monitor comes with step-down transformers so that it can be used on delta grounded, delta ungrounded or four-wire star systems of any voltage. **Principle Research & Development Corp, 200 Citizens Bldg, Aberdeen, SD.**

Circle 15, Reader Service Card

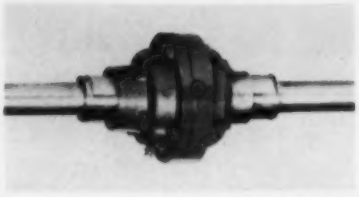
Variable-speed drives . . .

cover 1/50 to 1/3-hp range for applications such as metalworking machines, office machines, material handling devices. These drives use no tubes. Available in wide speed ranges offering stepless adjustment from zero to full speed. Circuit breakers protect armature. Remote control is compact and is said to utilize components rated in excess of normal operation. **Applied Technology Corp, 475 Fifth Ave, New York 17.**

Circle 16, Reader Service Card

10-hp differential . . .

for small vehicles and miscellaneous differential requirements is equipped with grease fitting for lubrication when mounted ex-

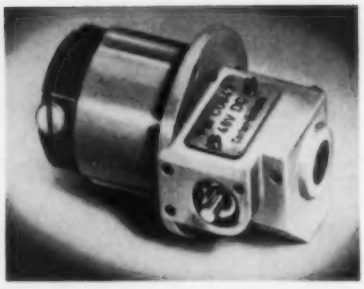


ternally. Can be run in oil inside differential case. Differential assembly has provisions for mounting sprocket, pulley or gears and hubs for antifriction bearings. Hardened alloy steel differential gears and pinions have automotive-type cut teeth. Alloy steel axle shafts are machinable or can be machined to specifications. **Warner Automotive Div, Borg-Warner Corp, 310 S Michigan, Chicago.**

Circle 17, Reader Service Card

Double gear reduction motor . . .

obtains output shaft speeds of 10 to 100 rpm. Output torque is 50 in.-oz max. Models of reversible fhp motor are available for inputs ranging from 6 through 48 v dc. Motor has permanent-magnet field. Design reduces span of shaft between bearings, compared with conventional units, and is said to prevent shaft distortion, minimize vibration, friction and wear. Heavy center bearing and over-size shaft at armature end are said to prevent misalignment. Brush and commutator



parts are accessible. Over-all length is about $2\frac{7}{8}$ in. Motor frame and gear case are die-cast aluminum. **Carter Motor Co, 2773-A W George St, Chicago 18.**

Circle 18, Reader Service Card

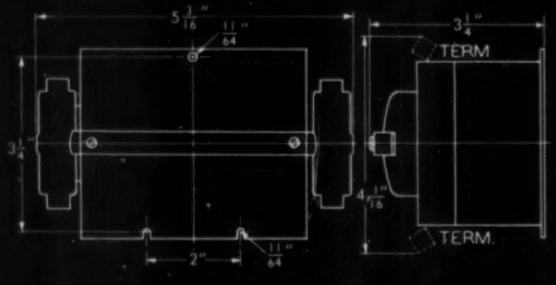
Flow-regulating device . . .

permits specified rate of flow regardless of inlet pressures. Designed for hot or cold water, it is offered in 49 flow rates from 2 to 50 gpm. Flow tolerances are maintained to 180 psi and temperatures to 160 F. Design is said to achieve low pressure drop and noiseless operation at any pressure. Flow control is available in $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, 1 and $1\frac{1}{4}$-in. pipe sizes. Can be used in such applications as balanced flow systems and specific flows to various units from one supply cource. **Automatic Controls Div, Hays Mfg Co, 450 W 12th St, Erie, Penna.**

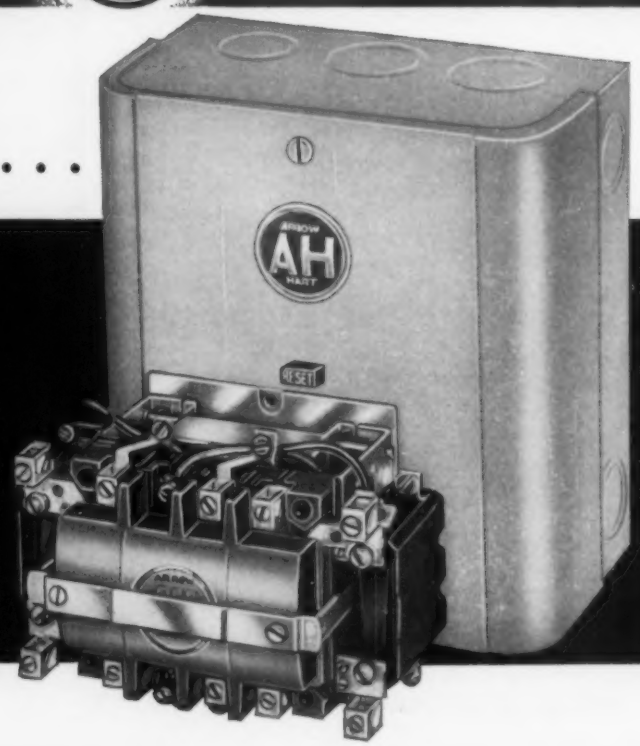
Circle 19, Reader Service Card

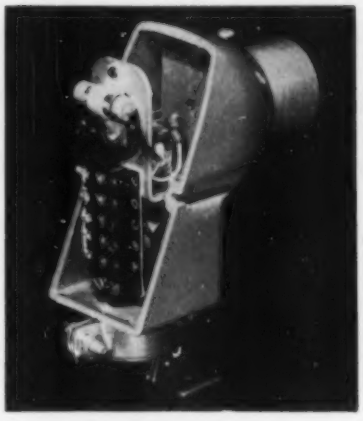
ARROW AH HART

1/2 THE SIZE OF CONVENTIONAL STARTERS . . .



SIZE 1 ILLUSTRATED
Approx. Wt. 3 lb.





Photoelectric relay . . .

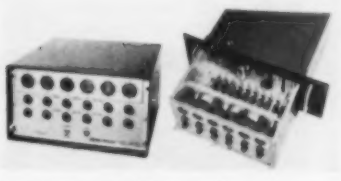
for indoor use on limit-switch-type applications where breaking of a light beam can be used to actuate an operation. Small-output relay is operated directly by cadmium sulfide power cell, eliminating tubes and separate control boxes. Relay draws full operating power of 57.5 v directly from transformer that supplies power to light source. Operates at 200 operations per minute max at min illumination level of 25 ft-c. Complete light beam cutoff is required to operate power cell. Expected life of output relay with 1 amp 115-v ac resistive load is rated at more than 1 million operations. Unit may be mounted in any position. **General Electric Co, Schenectady 5.**

Circle 20, Reader Service Card

Eddy-current tachometers . . .

are said to have accuracy of 1%. Measuring instrument, weighing less than 9 oz, is available in speed ranges of 0 to 2000, 0 to 4000, 0 to 6000, and 0 to 8000 rpm. Indicates direction of rotation. Hand-held unit has two moving parts and spindle mounted in sealed ballbearings. Packaged in plastic container with concave and convex neoprene adapters. **Boulin Instrument Corp, 10 First St, Pelham, NY.**

Circle 21, Reader Service Card



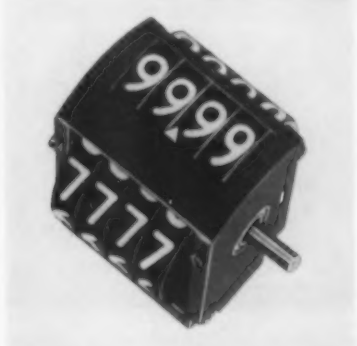
Preset controller series . . .

is transistor-equipped for heavy-duty industrial measuring and control functions. Units, enclosed in steel cabinets, have slide-out chassis for servicing. Operate directly from all types of sensing devices and have wide range of optional outputs. May be preset for zero to 180,000 counts per min., with instantaneous reset. Numerical readout consists of either glow counter tubes or in-line indicators. Two to six digit controllers, single or dual, are available with three or more preset numbers on any model. Cabinet model is 7 x 13 x 14 in. and weighs 25 lb. Rack panel model weighs 12 lb. **Dynapar Corp, 5150 Church St, Skokie, Ill.**

Circle 22, Reader Service Card

Internal pinion counter . . .

is miniature unit for vertical digital display-panel applications. Provides indications from 0000 to 9999 with return to 0000 in one-unit increments; optional



(Continued on page 78)

MOTOR CONTROLS

THE *NEW MODEL* 58 "RA" STARTER

This new starter features the exclusive Arrow-Hart "Right Angle" mechanism with magnet operating through a simple bellcrank lever. The resulting mechanical advantage lets a much smaller, lighter magnet outperform older, direct-acting types. Control size and weight are reduced by half . . . performance and dependability are greatly improved.

New Model 58 Size 1 Starters offer:

- **Wide Voltage Range Coils**
  Standard coil voltages are 110-120, 208-230, 440-480 and 550-600, at 60 cy.
- **Epoxy-Resin Encased Coils**
  Better protection against physical abuse, humidity, oil, fungus, shock, vibration, and other environmental conditions.
- **Wrap Around Enclosures**
  Make starters easier to install, wire, inspect and maintain.
- **Wiring Lugs**
  Make straight-thru front wiring easy.

Available in a complete line, NEMA Sizes 0 through 5, in Non-Reversing, Reversing Multi-Speed, Reduced Voltage Starters and others.

Write today for Motor Control Handy Reference Catalog No. 14 to The Arrow-Hart & Hegeman Electric Co., Dept. PE, 103 Hawthorn St., Hartford 6, Conn.

ARROW-HART of HARTFORD

Quality since 1890

MOTOR CONTROLS • ENCLOSED SWITCHES • APPLIANCE SWITCHES • WIRING DEVICES

plenty of cost-cutting possibilities in fastener design

BEFORE...
Separate Bolts, Nuts and Washers complicate inventories, increase assembly costs.
AFTER...
Washers as integral parts of bolts and nuts eliminate problems, speed assembly at lower cost.

BEFORE...
Appliance manufacturer installed leg leveling bolt; used square head fastener in crating.
AFTER...
Circle B leg leveling bolt designed with Phillips head, at no extra cost, now does both jobs.

IN THESE TWO CASES, savings were realized in every step of the operation from lower first cost of the fasteners through inventory to final assembly.

Important Savings often overlooked

Fasteners usually represent a small part of the total cost of assembly. However, this doesn't mean you can't save money on them. Actually, here is where cost reductions often can be made most readily.

By being familiar with a comparatively few basic principles affecting costs of headed parts, you can specify and buy them at most economical cost. With the assistance of specialized advice from an experienced company like Buffalo Bolt, you can often effect further savings.

As a guide in designing and buying headed parts, we have incorporated the important principles into a handy booklet complete with drawings and charts. From our field offices and plants, we can supply you with practical technical assistance, quotes and deliveries.

For a copy of the booklet, write our main plant at North Tonawanda. For immediate service, technical information or quotations, contact the office most convenient for you.

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Chicago	New York City	North Tonawanda
HArrison 7-2178	REctor 2-1888	JAckson 2400 (Buffalo)

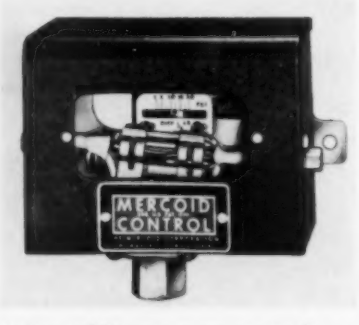
three-drum counter has three-digital indication. Counterclockwise rotation of right-hand shaft increases readings. One revolution advances or reduces counter 10 units. Equipped with fixed shade and decimal point to facilitate reading. Can be operated continuously at 300 rpm or intermittently at 600 rpm in temperatures of —67 to 212 F. Counter conforms to requirements of MIL-E-5272A. **Bowmar Instrument Corp, 8000 Bluffton Rd, Ft Wayne, Ind.**

Circle 23, Reader Service Card

Damped servomotors . . .

in sizes 11, 15 and 18 are said to operate to 392 F. All models of the 115-v 400-cps inertia and velocity-damped units have passivated stainless steel housings, corrosion-resistant, high-temperature laminations and encapsulated windings. Servomotors offer 0.63, 1.5 and 2.35 in.-oz torque at stall, respectively. Size 11 inertia-damped model is available with max additional damping factor of 155 dyne-cm sec per rad; velocity damped unit has adjustable damping range of 10 to 100 dyne-cm sec per rad. For the same models, size 15 units offer max additional damping factor of 700 dyne-cm sec per rad and adjustable damping range of 20 to 220 dyne-cm sec per rad. Size 18 units are available with max additional damping factor of 940 dyne-cm sec per rad and as specified with adjustable damping range of 40 to 330 dyne-cm sec per rad. **Helipot Div of Beckman Instruments Inc, 2500 Fullerton Rd, Fullerton, Calif.**

Circle 24, Reader Service Card



Adjustable pressure control . . .

has operating range of 1 to 20 psi and fixed differential of 0.5 psi. Operating point is set externally and visible on calibrated dial with pointer. Visible, hermetically sealed mercury switch is rated at 4 amp, 115 v or 2 amp, 230 v. The SPDT unit provides several different operations. Trip point is repetitive. Has two mounting ears or ¼-in. IPS bottom pipe connection. Size, 4⅛ x 3⅛ x 2⅞ in., and

(Continued on page 81)

SNAP RINGS FASTEN FOR KEEPS IN THIS NEW KIND OF AIR VALVE . . . ASSURE LONG, TROUBLE-FREE OPERATION

Experience has shown that the greatest percentage of all production-line mechanical failures can be traced to the improper use of screw-type fasteners: fasteners that, in fact, could better be called "looseners". Not so with MAC's revolutionary 4-way Dual-Seal Air Valve! There are no screws used to retain any of the valve parts. The valve body and solenoid cover utilize snap rings to complete an interlocking assembly *which can't work loose!* And the MACsolenoid itself requires no fasteners whatever . . . the parts interlock . . . preclude any loosening*.

Here's what the absence of threaded connections means to you: all functional valve parts are secured for keeps—assuring top performance and long operating life.

The versatile Dual-Seal and its larger counterpart, the Dual-Spool valve, are available throughout the complete range—¼" through 1¼" port sizes. Both valves have standardized and interchangeable bodies, bases and solenoids (single or double). Stroke movement is so slight that wear and metal fatigue failures are practically nonexistent. Other exclusive features include new add-a-unit manifolds, circular air-flow and electrical body plug-in connectors. You'll find this valve line offers *twice as much* as any other. Write now for more detailed information.

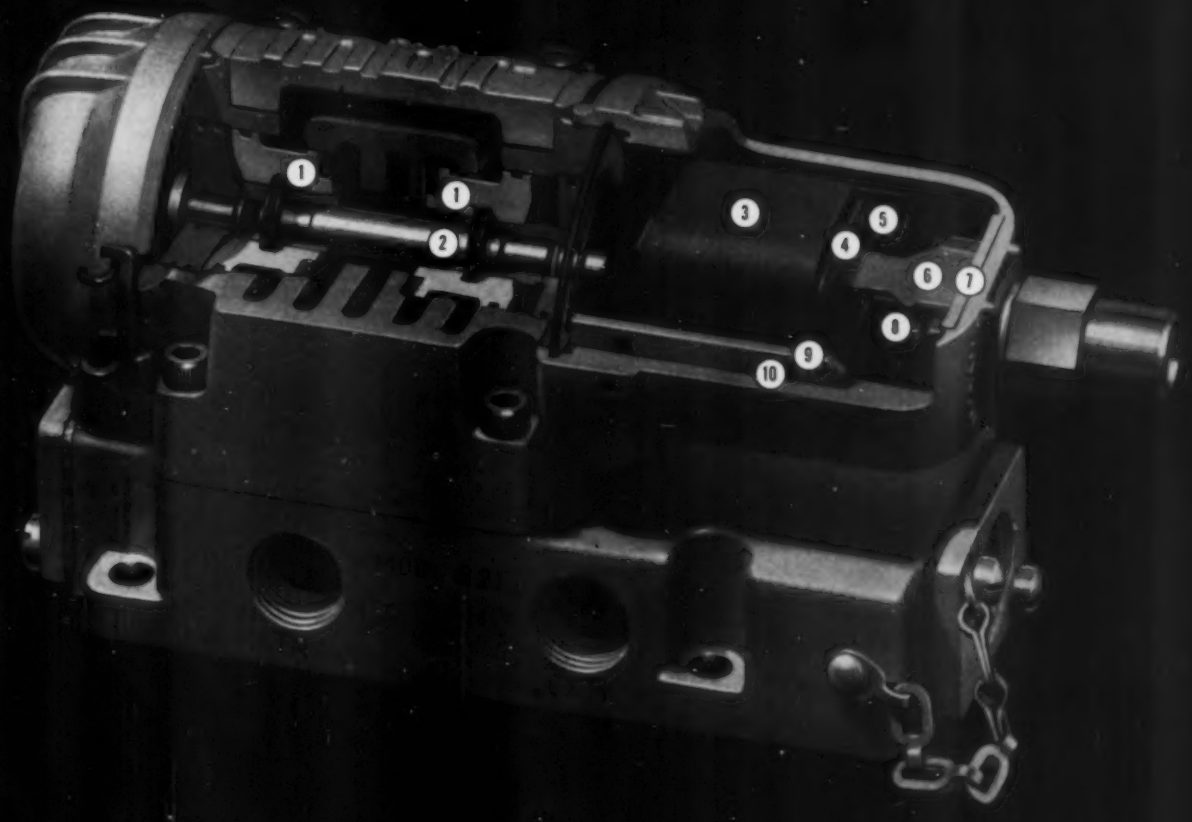
PRESIDENT

MECHANICAL AIR CONTROLS, INC.
19030 Capital, Oak Park, Detroit 37, Michigan

Export Representative: Ad Auriema, 85 Broad St., NYC 4

MAC

*The parts numbered below require no fasteners. They are:
1. Twin valves 2. Inner spool 3. Coil 4. Spacer 5. "C" frame 6. Plunger guide 7. Stop pad 8. Plunger 9. Mounting plate 10. Rubber insert.



Bullet after impact
Too tough for bullets . . . Cutler-Hammer Molded Magnet Coils work perfectly even after being struck by rifle bullets. What better proof Cutler-Hammer Motor Control can withstand the most punishing service?
Too tough for boiling oil . . . The performance of Cutler-Hammer Molded Magnet Coils remains unchanged even after being boiled in oil. Further proof Cutler-Hammer Motor Control stops trouble before it can start.
350°F
PROOF
OF DURABILITY

Cutler-Hammer Three-Star Motor Control is built to take it

If a rifle bullet can't pierce or shatter the Cutler-Hammer Molded Magnet Coil, what chance is there of it being punctured when an electrician's screwdriver slips or of it being damaged when the coil is dropped? If the Cutler-Hammer Molded Magnet Coil is impervious to boiling oil, what chance is there it can ever be penetrated by moisture or distorted by high ambient temperatures?

The strength and durability of these Cutler-Hammer Molded Magnet Coils are but one example of how Cutler-Hammer Three-Star Motor Control is built to take it. Why settle for less when Cutler-Hammer Control costs no more? Specify Cutler-Hammer Three-Star Motor Control . . . you can be sure it installs easier, works better, and lasts longer.

COLOR-CODED FOR RAPID, SURE IDENTIFICATION . . . No guesswork for electricians or stock men. Each color signifies the coil's voltage and frequency. Colors are permanent, too, can't rub off.

RED—110 volts A-c, 60 cycle
GREEN—208/220 volts A-c, 60 cycle
YELLOW—440 volts A-c, 60 cycle
BLACK—all other voltages and frequencies

CUTLER-HAMMER

Cutler-Hammer Inc., Milwaukee, Wis. • *Division:* Airborne Instruments Laboratory. • *Subsidiary:* Cutler-Hammer International, C. A.
Associates: Canadian Cutler-Hammer, Ltd.; Cutler-Hammer Mexicana, S. A.; Intercontinental Electronics Corporation.

CUTLER-HAMMER CONTROL CH

Molded magnet coils are standard in all Cutler-Hammer Three-Star Motor Control

NON-REVERSING STARTERS AND CONTACTORS

CONTROL RELAYS

OIL WELL PUMPING CONTROL

REVERSING AND MULTI-SPEED STARTERS AND CONTACTORS

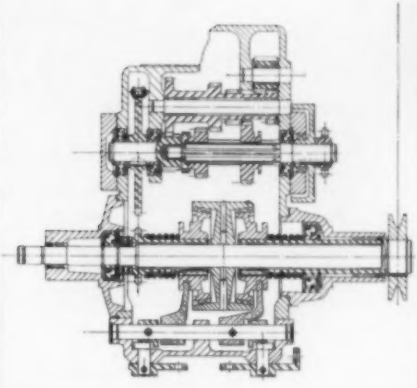
UNITROL MOTOR CONTROL CENTERS

AND MORE...

Write today for Pub. EN150-K-249. Cutler-Hammer Inc., Milwaukee 1, Wisconsin

weight, 1¾ lb, are particularly suitable for mounting where limited space is available or on wiring channels. Control is recommended for applications involving air or gases not injurious to steel or silver solder. Available after July 15. **Mercoid Corp, 4201 Belmont Ave, Chicago 41.**

Circle 25, Reader Service Card



Low-hp transmission . . . permits not only operation at built-in ratios but has auxiliary output shaft that operates at direct engine speed. Transmission has three speeds forward and one speed in reverse. Master clutch controls engagement of vehicle speeds; auxiliary clutch controls auxiliary output shaft. Both clutches are mounted on input shaft with auxiliary shaft mounted concentric to input shaft. Cone-type clutches, which run in oil, are actuated by cams. Actuating lever of main clutch is also actuating lever for transmission output-shaft brake when moved in opposite direction. Transmission is of sliding gear type. Shift lever is mounted at an angle directly on transmission to permit shifting at a considerable distance without requiring remote controls. Now in production are 5 to 10-hp units; transmissions up to 20 hp are available. **Adams Engineering Co, Solon, Ohio.**

Circle 26, Reader Service Card

Pressure-to-frequency . . . system combines reactance-controlled subcarrier oscillator and single-coil variable reluctance type pressure transducer in a single cylinder. Unit measures wide range of absolute, gage or differential pressures and is said to be stable over a wide range of temperatures (water-cooled transducer can measure gas pressures up to 3000 F). Furnished for operation at any IRIG band, as well as at subcarrier frequencies said to be higher than highest present IRIG band. Oscillator and transducer are matched so

(Continued on page 82)

DURA SEAL

THE ENGINEERED MECHANICAL SEAL

. . . spells out the answer to your sealing problems

D ecreases maintenance expense

U naffected by corrosives

R otates with the shaft

A djusts itself automatically

S eals abrasive liquids

E liminates scoring of shafts

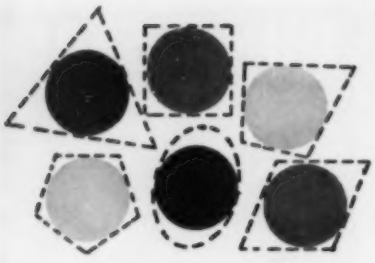
A daptable to standard stuffing boxes

L essens power costs

For free engineering counsel on your sealing problems . . . write

The PERFECT SEAL TRADE MARK

DURAMETALLIC CORPORATION
KALAMAZOO, MICHIGAN



Air 150 psi
Hydraulic up to 1500 psi
Meet JIC Standards
Series 101A

O-M Cylinders Fit Where Others Won't

THESE original space-saving O-M cylinders do more than fit into unusually close quarters too small to accommodate tie-rod cylinders of the same size bore. They save weight, improve appearance and assure smooth, dependable performance within a wide range of operating pressures. In addition, they are readily modified to serve in special applications, requiring semi-standard cylinders. And, the O-M Internal Locking Key, that makes it possible to orient the ports to any position, simplifies disassembly, inspection and service, eliminating alignment problems upon assembly. Completely interchangeable mounts and parts.

Available in 1½" to 8" bores with standard or heavy-duty piston rods.

Mail coupon today for 28-page Bulletin 101A replete with engineering drawings of cylinders, mounts, mounting brackets, capacity chart, and other performance data.

ORTMAN-MILLER MACHINE CO.
15 143rd Street,
Hammond, Indiana

☐ Have representative call
☐ Send Bulletin 101A

Name_____ Position_____

Company_____

Address_____

City_____ Zone____ State_____

that nonlinearity does not exceed 1%. Small, stiff diaphragm is only moving part, resulting in resistance to shock, vibration and acceleration. Noise-free characteristics of frequency modulation are applicable for uses requiring signal transmission over a cable to a remote computer or recorder. **Ultradyne Inc, PO Box 3308, Albuquerque, NM.**

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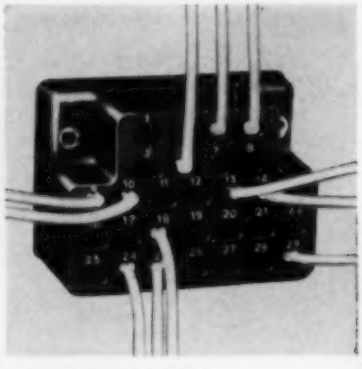


Terminal block kit . . .
permits assembly of a wide choice of circuit possibilities in industrial laboratory, experimental or engineering department. Block is central wiring terminus that is covered, insulated, and temperature resistant, with each brass terminal insulated from surrounding terminals. Rated 30 amp ac. Available in 12 to 29 terminal capacity. Accepts plug-in and snap-in type wire connectors. Same block can be supplied on production basis, completely assembled, to an established circuit. **Underwriters Safety Device Co, 4642 N Lamon Ave, Chicago 30.**

Circle 28, Reader Service Card

Continuous-flow enlarger . . .
for opaque or translucent originals utilizes reflex photocopying method. That is, image is reflected from original as it moves continuously across a lighted slot. Image travels up a light path through a sequence of mirrors and an enlarging lens until it reaches sensitized material on which copy is made. Sensitized material moves in synchronization with original. Originals can be up to 15 in. wide and any reasonable length. Camera enlarges up to seven times the original, with max width of 30 in., or reproduces to same size. Sensitized paper is unrolled from light-tight magazine and passes through copying point at fixed speed of 10 fpm. Camera can be operated, loaded and unloaded in normal daylight. Unit is 8 ft 9 in. high. Weighs 1900 lb. **Peerless Photo Products Inc, Shoreham, LI, NY.**

Circle 29, Reader Service Card

COST-CUTTING PRODUCTION TEAM

The two-way answer to assembly problems

Assembly problems are a designer's problem, too. Milford offers tubular rivets made to high quality standards to assure a better finished product . . . a wide line of Automatic Riveters that assemble your "brainchild" with care, precision and economy.

For the answers to assembly problems *. . . get in touch with Milford first.*

THE MILFORD RIVET & MACHINE CO.

MILFORD, CONNECTICUT • HATBORO, PENNA.
ELYRIA, OHIO • AURORA, ILL. • NORWALK, CALIF.

News! The best features of
modern bearing design combined and refined in

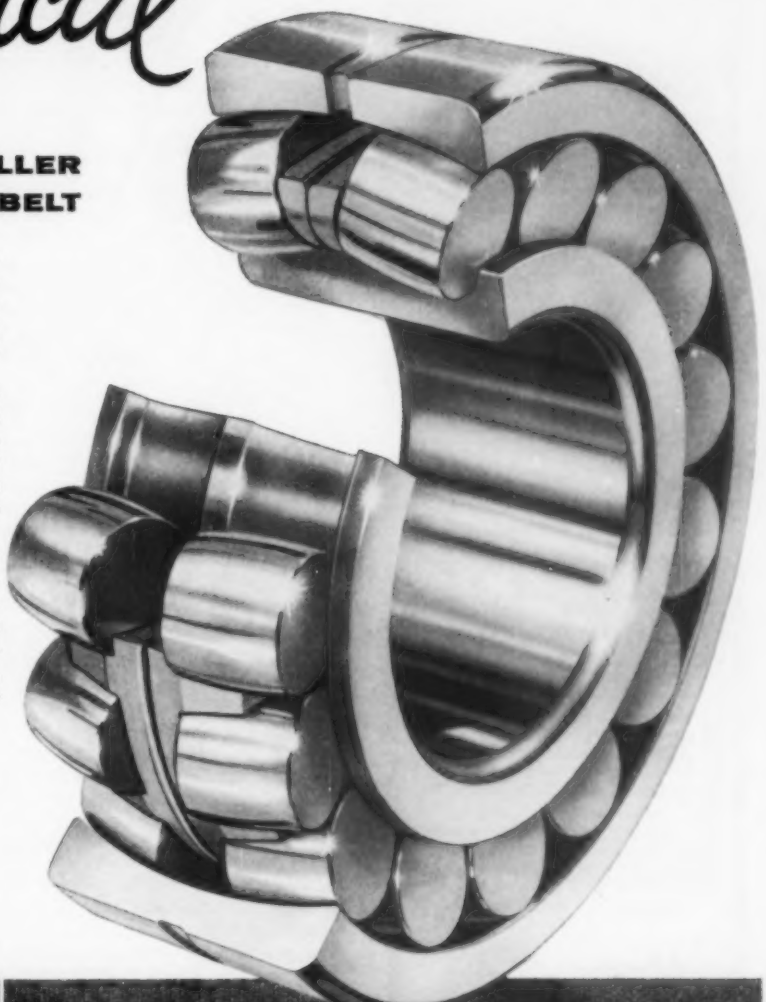
Spherical

SELF-ALIGNING ROLLER BEARINGS BY LINK-BELT

BIG, mirror-smooth convex rollers *plus* heavy, broad-shouldered inner race *plus* centrifugally-cast bronze, precision-machined retainers! Only from Link-Belt do you get ALL that is best in modern bearing design.

Individually, these elements represent major improvements on accepted design concepts. Collectively, they constitute the most efficient spherical roller bearings available . . . promise unequalled economies, whatever the application.

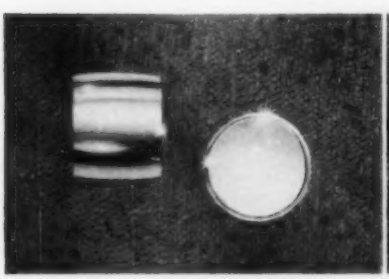
Your Link-Belt office will gladly explain the many performance advantages evolved with this new design. It can furnish full data on industry's most complete line of ball and roller bearings . . . pillow blocks and flanged, flanged-cartridge, cartridge, and take-up blocks.



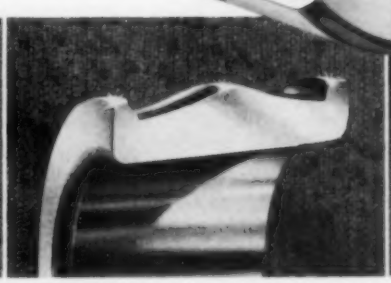
LINK-BELT

MANUFACTURERS OF SELF-ALIGNING BALL AND ROLLER BEARINGS

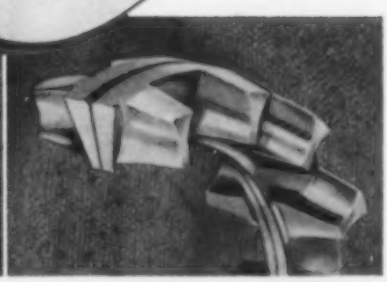
LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. Plants, Sales Offices and Distributors in All Principal Cities. 14,819-A



BIG, HIGHEST-CAPACITY ROLLERS. Each bearing has a maximum number of rollers —as large as possible, yet all components are in optimum balance.



HIGH, HEAVY INNER RACE FLANGES present convenient hold for assembly and removal of bearing without cutting away shaft, avoid any need to skimp on shaft shoulders.



PRECISION-MACHINED, CENTRIFUGALLY-CAST BRONZE RETAINERS have many times more support and ability to withstand high stress. They are not stampings. Design assures maximum bearing efficiency.

GENERAL INDUSTRIES

Smooth Power

AC MOTORS

1/1000 H.P. to 1/35 H.P.

MODEL B
1/80 H.P. to 1/35 H.P.
4-pole, 4-coil shaded pole
AC induction type

...for a standard line of motors adaptable to hundreds of applications

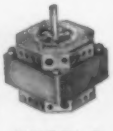
RELY on GI

Fractional H. P. Motors

General Industries' standard line of motors is adaptable, with slight variations, to literally thousands of applications. This means that your motor requirements can most likely be met without additional time-consuming engineering.

If you are currently using fractional horsepower motors, or are planning a product that calls for their use, phone or write General Industries. We'll gladly make recommendations—without obligation.

MODEL A
1/500 H.P. to 1/45 H.P. 2-pole shaded pole
AC induction type



MODEL D
1/90 H.P. to 1/45 H.P. 4-pole, 4-coil shaded pole
AC induction type

Write today for catalog sheet and quantity-price quotations.

THE GENERAL INDUSTRIES CO.

DEPARTMENT GK • ELYRIA, OHIO

CATALOGS and BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover.

INDUSTRIAL PUMPS—Catalog, 72 pp. Covers centrifugal and rotary pumps rated from 1/20 to 5 hp; with delivery of 1 pt to 148 gpm. Includes descriptions and specifications of pump parts and accessories. Thumb-indexed for major sections. Pioneer Pumps, Paris Products Div, Detroit Harvester Co, 21800 Greenfield Rd, Oak Park 37, Mich.

Circle 30, Reader Service Card

DRAWN CLOSURES—General catalog, 72 pp. Lists standard round, square and rectangular cases, standard covers, special cases and MIL types with dimensions and specifications. Also included is information on facilities for subassembly and sheet metal fabrication work. Hudson Tool & Die Co Inc, 18-38 Malvern St, Newark 5, NJ.

Circle 31, Reader Service Card

HYDRAULIC EQUIPMENT—Equipment digest, 52 pp. A compilation of principles involved in use of the equipment, application stories and descriptions of products available from Bowser and its subsidiary companies. Bowser Inc, 1300 E Creighton Ave, Ft Wayne 2, Ind.

Circle 32, Reader Service Card

ADJUSTABLE-SPEED DRIVE EQUIPMENT—Bulletin GB-3, 16 pp. Discusses eddy-current couplings, drives, brakes and dynamometers, magnetic friction clutches and brakes. Describes various models, principles on which equipment operates, and design advantages. Dynamatic Div, Eaton Mfg. Co, Kenosha, Wis.

Circle 33, Reader Service Card

SHORT-RUN STAMPINGS—Manual, 14 pp. Design suggestions for reducing costs. Included for discussion are quantities, materials, tolerances, clearances, blank design, piercing and bending. Small Lot Stamping Institute, PO Box 7062, Cleveland 28, or members of the Institute.

Circle 34, Reader Service Card

RUST PREVENTION—Booklet, 20 pp. Presents basic information on rust, its causes and application of preventives. Includes data on various types of rust-preventing liquids available from company. Rust-Lick Inc, 755 Boylston St, Boston 16.

Circle 35, Reader Service Card

VERTICAL-HELICAL SPEED REDUCERS—Bulletin 5908, 20 pp. Contains specifications, dimensions and characteristics for both double and triple-reduction units. Includes selection instructions for many types of installations. Western Gear Corp, Industrial Products Div, PO Box 126, Belmont, Calif.

Circle 36, Reader Service Card

SOLENOID VALVES—Catalog 444, 36 pp. Lists line of over 200 bronze and stainless steel solenoid valves. Gives specifications, performance data, applications and optional features. Cutaway drawings identify valve parts and illustrate operation. Prices are included. Atkomatic Valve Co, 545 W Abbot St, Indianapolis.

Circle 37, Reader Service Card

MARTENSITIC STAINLESS STRIP—Booklet, 16 pp. Presents information on how martensitic stainless steels, usually alloyed with chromium and molybdenum, can be used in many applications previously restricted to straight high carbon strip steels. Three types of strip are covered, with data on analysis, heat treating, recommended applications. Uddeholm Co of America, 155 E 44th St, New York 17.

Circle 38, Reader Service Card

ROTOR-TYPE VALVES—A data file about 10 pp. Describes operation, dimensions and specifications of two, three and four-way valves. Clark Engineering & Mfg Inc, 1820 Layard Ave, Racine, Wis.

Circle 39, Reader Service Card

SERVOMOTORS—Catalog 5000, 20 pp. Lists and describes basic models of size 8 to 29 servomotors. With dimensional drawings and physical, electrical and mechical characteristics. John Oster Mfg Co, Avionic Div, 1 Main St, Racine, Wis.

Circle 40, Reader Service Card

PROCESS CHEMICALS FOR METAL FINISHING—Data file, 9 pp. Discusses characteristics, properties and applications of chromate conversion coatings for nonferrous metals, clear protective coatings for all metals, plating brighteners and process chemicals and supplies. Allied Research Products Inc, 4004-06 E Monument St, Baltimore 5.

Circle 41, Reader Service Card

WIRES AND CABLES—Bulletin series. Contain descriptions, specifications, electrical characteristics of wire and cable products, together with charts and graphs. Subjects include flexible 1000 F wire and cable, multiconductor MIL-C-3432A cable, small-diameter high-voltage, high-tempera-

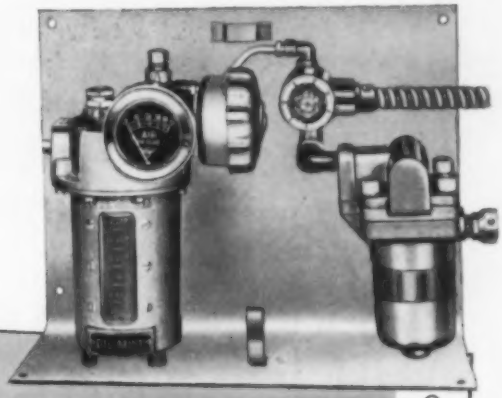
(Continued on page 87)

How to choose a

LUBRICATION SYSTEM

that provides constant, uniform lubrication

at savings of up to **90%**



use this handy check list:

Will your lubrication system be fully automatic? Oil-Mist starts and stops at the touch of your machine switch.

Will the system that you choose cut oil consumption by 90%? With the Alemite Oil-Mist System you can get better bearing lubrication with only 1/10th as much oil as required by other methods.

Will your lubrication system reduce bearing temperatures? The answer is "yes," if it's an Alemite Oil-Mist System. Reduction in fluid oil friction—plus air flow through bearing—greatly cuts bearing heat.

Will your system extend bearing life? You can definitely count on it, if you choose Oil-Mist. Oil-Mist has extended the service life of many bearings, even under adverse operating conditions, from 10 to 12 times!

Will you have a continuous system? Oil-Mist constantly feeds a uniform volume of fresh oil to each bearing. No oiling schedules. No feast-or-famine lubrication.

Does it protect against contamination? Satisfied Oil-Mist users say yes. A constant flow of clean, air-oil mixture—Oil-Mist—through bearings keeps out dirt and abrasives. Oil-Mist also eliminates wasteful oil handling and applying.

Lubricates any bearing on any machine in One Of Three Ways:

Oil-Mist for high speed anti-friction type of bearings.

Oil Spray for low speed anti-friction and open and enclosed gears and chains.

Condensed Oil for plain bearings, slides, ways, vees, cams, and rollers.

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☐ Please send me a free copy of your Oil-Mist catalog.

☐ Please have your Alemite Lubrication Representative arrange a no-obligation demonstration.

Name .....

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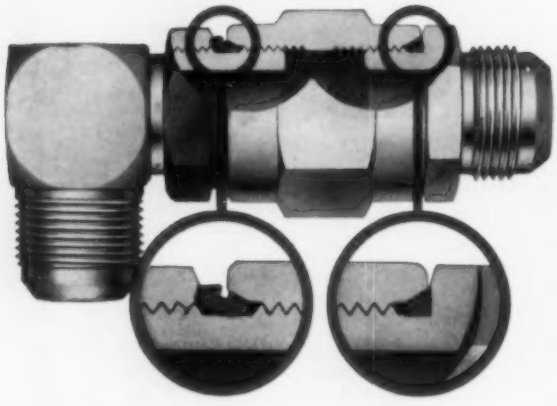
SEE YOU AT BOOTH 1614

HAVING PORT SEALING PROBLEMS?

L and L

CAN HELP YOU WITH

"CN" METAL SEAL



SOLVE FLUID LEAKAGE

Wedging action of metal sleeve against taper in the port makes pressure-proof joint.

Positive metal seal is unaffected by fluids, temperature, high pressures or vibration.

"Connect up with L and L"
Write for Catalog CN-59

Representatives in Principal Cities

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P.O. Box 292
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86 CIRCLE 142 READER SERVICE CARD

THE SHAPE OF THINGS IN MOLDED RUBBER

MOLDED BOOT MINUS STOCKINGS
CUTS COST FOR LIFT TRUCK MANUFACTURER

A protective boot for hydraulic lift and tilt mechanism was needed by a manufacturer of gasoline powered lift trucks. In addition to having resistance to hydraulic oils, automotive greases, dirt and sunlight, it had to maintain good flexing qualities without checking or cracking.

The print specified a boot with stockinette base. Lab technicians at Acushnet successfully eliminated the use of stockinette as a base. The boot was compression molded entirely of an Apco neoprene compound. Further cost reductions were effected by dieing out the flange area and holes permitting a choice of various shaped mounting areas.

Result! Big savings in mold cost; cleaner, more precise parts.

Designing a new molded rubber or silicone part? Immediate technical assistance is available from Acushnet in part design, custom compounding and molding techniques.

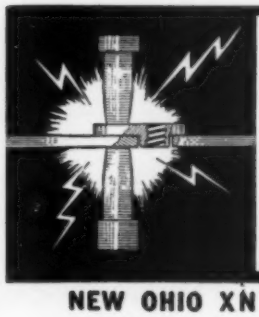
What's Your Shape?

Send for Acushnet "Rubber Data Handbook."

Acushnet ACUSHNET PROCESS COMPANY
NEW BEDFORD MASSACHUSETTS

... *Precision Molded* RUBBER, SILICONES - "APCOTITE" BONDING
Address all communications to 768 Belleville Ave., New Bedford, Mass.

CIRCLE 143 READER SERVICE CARD



Note the small pilot diameter which eliminates oversize sheet perforations.

Patent Applied For

Note the recessed target electrode area which permits welding nuts 6-32 to ⅜-16 to sheets .025 to .187 thick with low KVA Welders

NEW OHIO XN SPOTWELD NUT

FOR FASTER AND BETTER JOINING OF YOUR PRODUCT COMPONENTS

This nut which is applied by portable, rocker arm or press type spot welders becomes the primary fastener in your fastener assemblies. It offers these distinctive advantages:

- LIGHTNING-FAST APPLICATION (By spot welding)
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- SPLIT-SECOND ASSEMBLY OF PRODUCT COMPONENTS (Made possible by pre-attached primary fastener)
- SHIPMENT FROM STOCK

Samples and information furnished upon request.

The OHIO WELD FASTENERS Primary Fastener in Fastener Assemblies

THE OHIO NUT AND BOLT CO.
45 FIRST STREET • BEREA, OHIO

CIRCLE 144 READER SERVICE CARD

ture conductors, silicone rubber insulated single and multiconductor cable and coaxial cables. Boston Insulated Wire & Cable Co, 25 Bay St, Boston 25.

Circle 42, Reader Service Card

SELENIUM RECTIFIERS—Brochure, 6 pp. Contains basic characteristics of rectifiers with temperature derating table as well as overload and allowable-currents-under-various-forced-cooling curves. Includes general design information on circuits, code designation chart, dc voltage chart and bracket dimensions. Rectico Inc, 963 Frelinghuysen Ave, Newark 12, NJ.

Circle 43, Reader Service Card

CONDULETS FOR CORROSIVE LOCATIONS—Bulletin 2699, 16 pp. Corrosion-resistant properties of various metals and finishes used in condulets are discussed, with charts showing applications of each. Lists condulets for hazardous and non-hazardous locations. Crouse-Hinds Co, Syracuse 1, NY.

Circle 44, Reader Service Card

INDUSTRIAL THERMOMETERS — Catalog DT2-58, 12 pp. Discusses manufacturing and testing procedures and gives specifications and descriptions of bimetal dial thermometers. Rochester Mfg Co, 100 Rockwood St, Rochester 10, NY.

Circle 45, Reader Service Card

POWER SUPPLIES—Catalog E-59 A, 12 pp. Covers general specifications, ratings and dimensions of dc power supplies, ac line voltage regulators, airborne radar power supplies and static inverters and converters. Perkin Engineering Corp, 345 Kansas St, El Segundo, Calif.

Circle 46, Reader Service Card

PERFORATING, SLITTING AND BLANKING—Catalog 57, 16 pp. Discusses suggested applications, materials, how to specify; and various patterns are illustrated. With specifications. Perforating Industries Inc, 163 W Westfield Ave, Roselle Park, NJ.

Circle 47, Reader Service Card

INDUCED-DRAFT FANS—Bulletin L-3, 16 pp. Features, dimensions and ratings are given for line of fans, supplemented with drawings, photos and schematic diagrams of installations. Lehigh Fan & Blower Div, Fuller Co, Catasauqua, Penna.

Circle 48, Reader Service Card

COATED TUBINGS — Catalog, 6 pp. Physical and electrical specifications, application information and characteristics of line of coated tubings are given. Cross-reference chart presents NEMA temperature rating of each type of tubing, class and type, voltage grades, standard and

(Continued on page 90)

Count Control

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FOR AUTOMATING INDUSTRIAL PROCESSES

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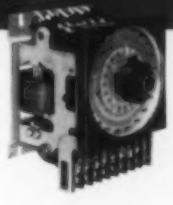
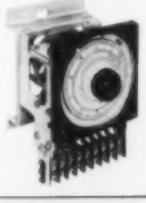


model HZ4
MICROFLEX RESET COUNTER

Use to control an operation for a preset number of counts. Has spring reset to "0." Dial ranges 19, 400 and 1,000 counts.

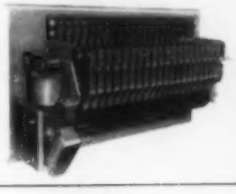
Ask for bulletin 720.



model HZ200
ADD-SUBTRACT COUNTER

Add-Subtract counter — operates from ADD pulses which trip switch at maximum limit — and SUBTRACT pulses which trip switch at "0" limit.

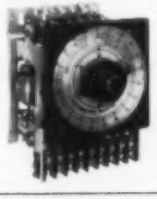
Ask for bulletin 740.



model MT
STEP SWITCH

Use for sequence control from pulses — 19 contacts — 60 cycle coil-break out cam lugs.

Ask for bulletin 780.



model HZ6
MICROFLEX REVOLUTION COUNTER

Use to control an operation as a function of mechanical movement — drive shaft can be mechanically connected to machine, spindle, conveyor, etc.

Ask for bulletin 730.

model HM
MULTIFLEX (Multiple Circuit) TIMER

Use for sequence control of 1 to 7 circuits. With shaft drive for mechanical connection to an external drive mechanism.

Ask for bulletin 130.

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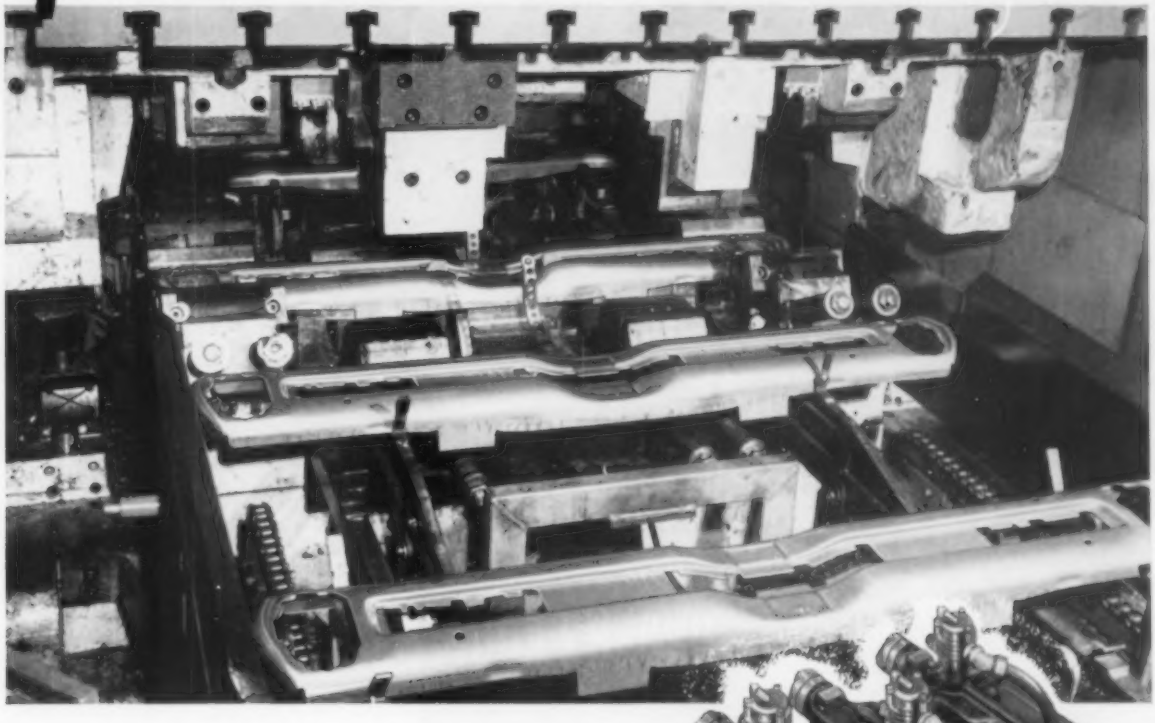

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Circle 49, Reader Service Card

SHAFT ANGLE ENCODERS—Bulletins 0858, 0958, 1058, 1158 and 1258, 4 pp each. Each describes one of five models of analog-to-digital shaft angle encoders. Includes features, specifications, and schematic diagrams. Industrial Products Div, Baldwin Piano Co, 1801 Gilbert Ave., Cincinnati 2.

Circle 50, Reader Service Card

RELAYS—Folder, 8 pp. Electrical ratings and specifications of a wide assortment of stock relays, steppers, solenoids, contactors, rectifiers and related components. Universal Relay Corp, 42 White St, New York 13.

Circle 51, Reader Service Card

PNEUMATIC VALVES—Condensed catalog 58, 16 pp. Dimensional and parts information on more than 40 types of pneumatic valves. Valves are grouped according to methods of operation. Ross Operating Valve Co, 120 E. Golden Gate Ave, Detroit 3.

Circle 52, Reader Service Card

RIGHT-ANGLE POWER TRANSFER UNITS—Bulletin 592, 6 pp. Specifications and design information on redesigned line of 17 models. With dimensional drawings and tabular data and single-sheet price list. Crown Gear, Sub Harrington & Richardson Inc, 320 Park Ave, Worcester 10, Mass.

Circle 53, Reader Service Card

STAINLESS PIPE, TUBE—Bulletin U, 8 pp. Describes low-carbon stainless steel pipe and tube, including variations, tolerances. Union Steel Corp, Union NJ.

Circle 54, Reader Service Card

TEFLON-COATED GLASS FABRIC—Brochure, 4 pp. Includes properties of five types of coated fabrics, adhesive tapes and yarn, sewing thread, lacing tape and woven fabric. Commercial Plastics & Supply Corp, 628-30 Broadway, New York 12.

Circle 55, Reader Service Card

V-BELT PULLEYS—Catalog, 4 pp. Specifications on standard sizes of single-groove V-belt pulleys for flip equipment. Nagel-Chase Mfg. Co, 2811 N Ashland Ave, Chicago 13.

Circle 56, Reader Service Card

FLEXIBLE AND RIGID CELLULAR PRODUCTS—Bulletin, 4 pp. Contains physical properties and application data. Describes company and services. Toyad Corp, PO Box 30, Latrobe, Penna.

Circle 57, Reader Service Card

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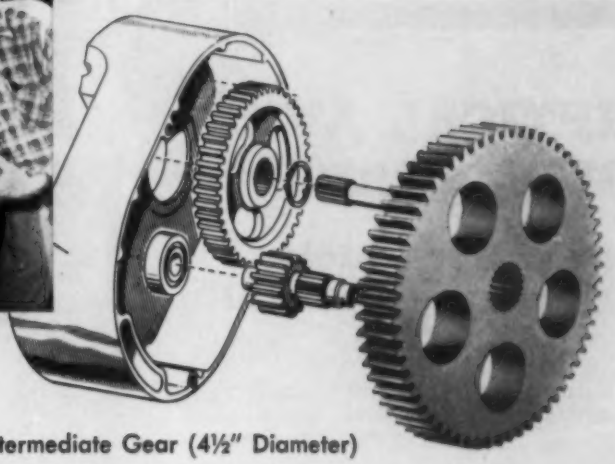

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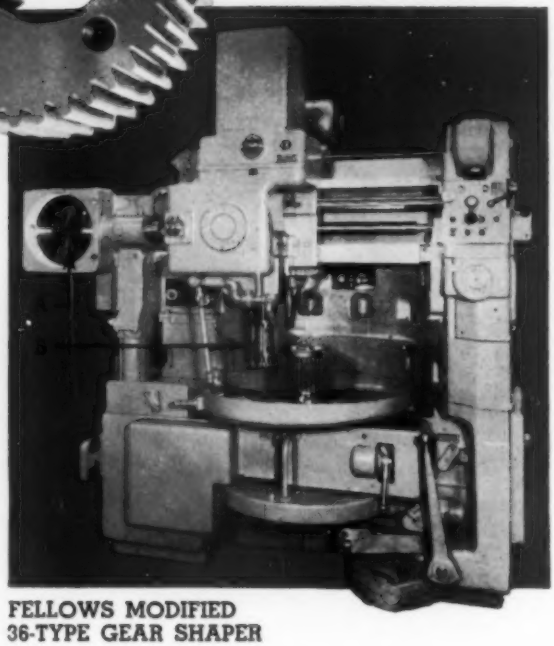

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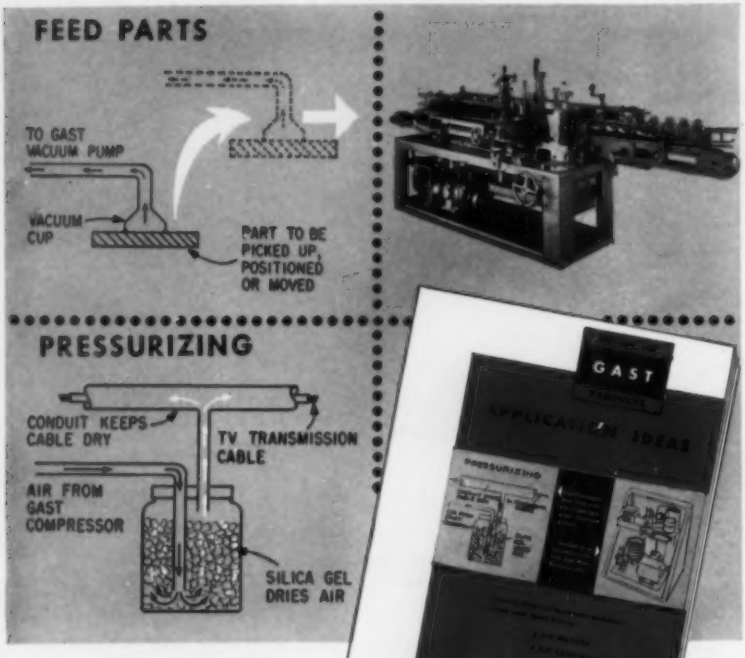

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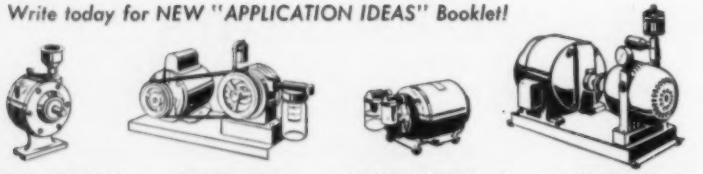

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DESIGN ABSTRACTS

Pressurized Cylinders for High Temperatures

General equations for the stresses in a thick-walled cylinder in a state of plane strain are derived, considering "steady-state" creep. Numerical examples are included to illustrate effect of geometry and material properties.

"Design of Pressurized Cylinders for High-temperature Applications," J F Traexler, Westinghouse Electric Corp, ASME paper 59-Met-8, 29 W 39 St, New York 18.

Design Factors Affecting Machine Efficiency

This discussion is intended mainly to help potential machine tool buyers in selecting equipment. However, the topics covered (flexibility, accessibility, tool changing, electrical arrangement, work height, identification) should be of interest to designers of many other types of production equipment.

"Design Factors Affecting Machine Efficiency," K O Tech, Cross Co, SAE paper 415, 485 Lexington Ave, New York 17.

How Wall Thickness Affects Stress-Rupture Life of Tubes

Data obtained from application of internal pressure to tubular specimens is compared with data from standard tension-bar specimens from same heats. Dimensionless parameter method is presented which provides satisfactory correlation for three materials, for test temperatures and a wide range of wall thickness.

"Effect of Wall Thickness on Stress-rupture Life of Tubular Specimens," Tucker, Coulter and Kooistra, Babcock & Wilcox Co, ASME paper 59-Met-11, 29 W 39 St, New York 18.

Solid Additives in Fluid Lubricants

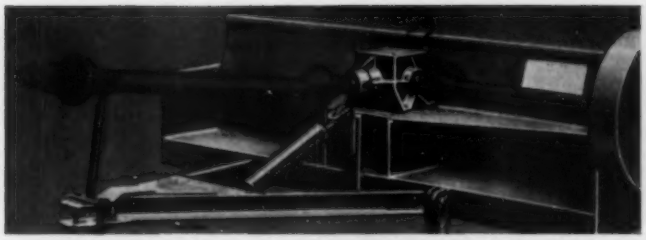
How solid additives effect the coefficient of friction is described.

"Effect of Solid Additives on Fluid Lubricants," H L Herzig, Climax Molybdenum Co, Lubrication Engineering, April 1959, 84 E Randolph St, Chicago 1.

Prealloyed Metal Powders

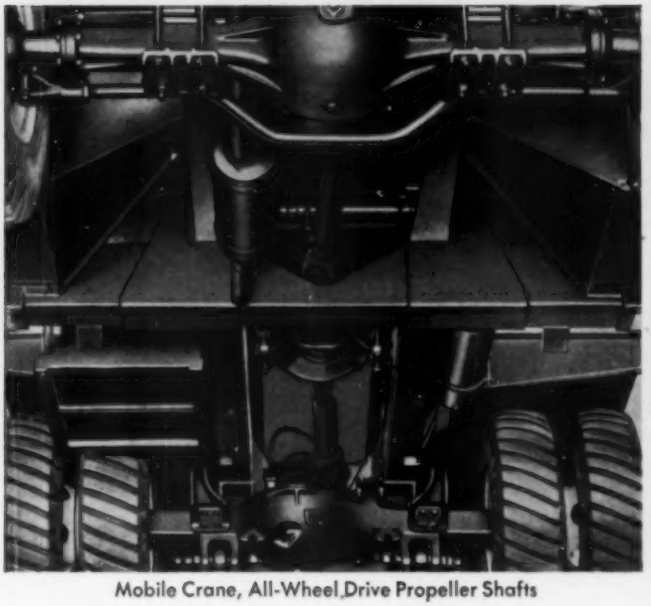
Characteristics, properties, fabrication methods, application of metal

(Continued on page 97)



Shielded Farm Implement Drive, Tractor P.T.O. to Gear Box

Differential to Drive Sprocket, Straddle Truck



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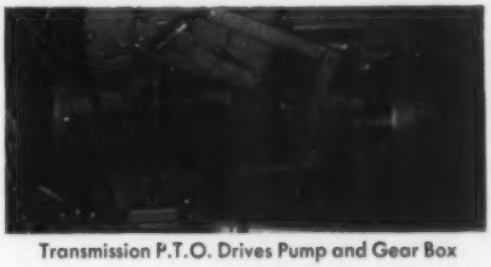

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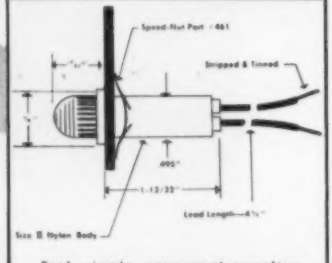

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CIRCLE 154 READER SERVICE CARD

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powders made from such molten alloys as stainless steels and alloy steels are discussed.

"How to do More With Prealloyed Powders," W L Batten, Vanadium-Alloys Steel Co, Metal Progress, April 1959, 7301 Euclid Ave, Cleveland 3.

Noise

Series of two articles discusses effects of noise and methods of designing noise control into manufactured products.

"Noise—Its Nature, Behavior and Reduction," D M A Mercer, University of Southhampton, Engineering Materials and Design, April and May 1959, Drury House, Russell St, London W C 2, England.

Investment Casting

Suggestions for designing parts to be made by investment casting are given. Tolerances, radii, straightness, flatness, concentricity, roundness, angles, parallel sections, holes, size and weight, minimum section thickness, serrations, finish, threads, parting lines and gating, draft, fillets are discussed.

"Designing for Investment Casting," Tool Engineer, April 1959, 239 E Chicago St, Milwaukee, Wis.

Residual Stress and Brittle Fracture

Effects of residual stress on fracture occurring under various conditions are discussed. A theoretical study is also included, based on an extension of Griffith's theory to the stress field containing residual stress. Suggestions as to material selection, methods of applying stress, stress relief treatments and testing procedures are also given.

"Effect of Residual Stress on Brittle Fracture," Masubichi and Kihara, University of Tokyo, AWS paper 8-A, 33 W 39 St, New York 18.

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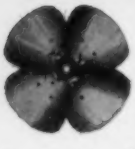

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TUCKER AND WILLS. Minneapolis-Honeywell Regulator Co, Brown Instruments Div, Philadelphia. 6 x 9, 303 pp. $5.

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Cast Age-hardenable Austenitic Steels

PB 131733. US Dept of Commerce, Office of Technical Services, Washington 25, DC. 8 x 10, 14 pp. 50¢.

Problems involved in specifying cast adaptations of wrought materials and a description of the process are covered in this report on cast age-hardenable austenitic steels. It is valuable because it gives an idea of how much work is required and the compromises, such as chemical composition, mechanical and physical properties, that may have to be accepted.

Engineering Mechanics–Dynamics

H L LANGHAAR, A P BORESI. McGraw-Hill Book Co, 330 W 42nd St, New York 36. 9 x 6, 719 pp. $5.

In addition to standard material on engineering dynamics, this book includes many topics not ordinarily found in an introductory text. These include: the theory of curvature, an interpretation of centripetal and tangential acceleration with the aid of vector derivatives, a discussion of kinematic and dynamic frames of reference, elements of the theory of physical dimensions, the theory of planetary motion, and the idea of a control surface, with the related momentum theorem in fluid mechanics.

The concept of mass is introduced by Newton's law of gravitation, in the same way that electrostatic charge is defined by Coulomb's law. This approach establishes the proportionality between mass and weight in a given locality. The concept of dimensions, and the conventional units of mass, length, time and force are discussed in detail.

Three-dimensional kinematics and dynamics are developed with the aid of vector analysis. There is a chapter on vibration theory, and the general concept of energy is developed together with the general energy equation for flow machines. There are 201 review questions at the ends of the chapters and a large number of solved illustrative examples. Answers are given for about half of the more than 500 problems.

Plastic Analysis of Structures

PHILIP G HODGE Jr, PhD. McGraw-Hill Book Co, 330 W 42nd St, New York 36. 5½ x 9, 364 pp. $10.50.

For many generations, engineers have based the analysis and design of structures on a linear theory of elasticity. Recently, however, there has been increasing interest in the important field of ultimate-strength, limit, or plastic design and analysis. This book presents the techniques necessary in the analysis of structures beyond the elastic limit and emphasizes the conditions under which a plastic analysis is appropriate.

The theory is presented completely and systematically. Structures treated include beams and frames in bending,

(Continued on page 101)

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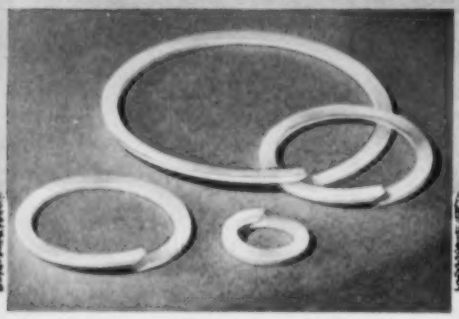

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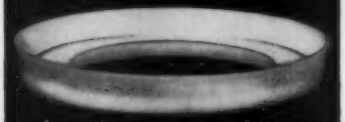

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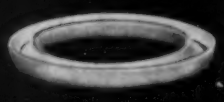

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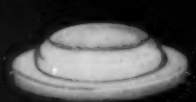

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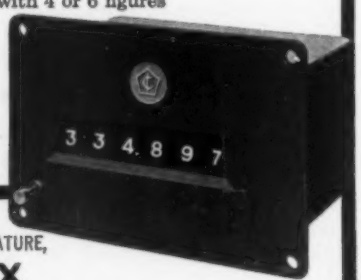

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beams under combined stresses, plates, shells and slabs with cutouts. Primary attention is given to the determination of stresses under static loads; but displacements, variable loadings, minimum weight design and dynamic loadings are also treated. The subject matter is approached from the viewpoint of limit analysis. Two basic theorems are emphasized which enable lower and upper bounds on the load-carrying capacity of structures to be determined by independent consideration of static and kinematic conditions respectively.

The subject matter is presented at as elementary a level as possible. For this reason, the book is divided into two parts. Part I, Bending of Beams and Frames, treats the application of plastic methods to frame-type structures whose principal strength lies in their resistance to bending. It also deals with such topics as elastic plastic deformations, variable and repeated loading, and direct procedures of design. Part II, Structures Under Combined Stresses, is primarily concerned with combined stresses in beams, circular plates and cylindrical shells.

Letter Symbols for Hydraulics

(ASA Y10.2-1958) Prepared by Sectional Committee on Letter Symbols. American Society of Mechanical Engineers, 29 W 39th St, New York 18. 8½ x 11, 12 pp.

This is a short list of symbols and is consistent for the following fields of hydraulics: hydraulic turbo-machinery; water waves; sediment transport; hydrology; industrial hydraulics; water hammer, and naval architecture.

High-temperature Effects in Aircraft Structures

Edited by NICHOLAS JOHN HOFF. Pergamon Press, 122 E 55th St, New York 22. 9½ x 6, 357 pp. $12.

High-speed aircraft have presented structural designers and analysts with the additional problem of high-temperature conditions in which normal structural analysis cannot be applied. This book is a compilation of contributions by numerous authors dealing with the reaction of various structural materials and structural phenomena at elevated temperatures. Difficulties in handling such materials as plastics, structural ceramics, metal and other nonmetallic materials are covered by different authors. The effects on these materials and the relationship of such phenomena as buckling, creep, relaxations and fatigue are discussed. The advanced research on high-temperature problems will be of interest to structural and materials engineers.

Welding Handbook—Fourth Edition, Section 2

American Welding Society, 330 West 39th St, New York 18. 6 x 9, 550 pp. $9.

Three o'clock welding—spread arc welding. Are these terms new to you? Then you should read this section of the welding handbook. It covers, in 12 chapters, all the welding processes. Chapters do not just rehash the old welding handbook, but are revised to cover all the newer adaptations of older processes.

Most important is the last chapter on welding symbols. These were completely revised last year, outdating older symbols. If you work with weldments or do any specification of welds, buy or borrow this section of the welding handbook and keep it handy.

Compact Heat Exchangers

KAYS AND LONDON. McGraw-Hill Book Co Inc, 330 W 42nd St, New York 36. 8½ x 11, 156 pp. $6.

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(Continued on page 102)

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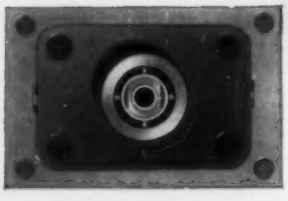

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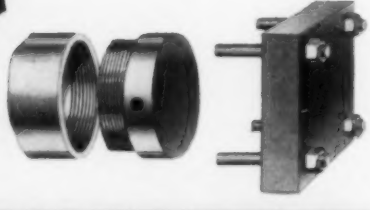
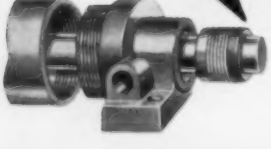


For the Maintenance Man



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Other Books of Interest

Fatigue Strength Reduction Factors for Inclusions in High-strength Steels.
PB 131816. Cummings, Stulen, Schulte. Office of Technical Services, Dept of Commerce, Washington 25, DC. 8 x 10½, 32 pp. $1.

Plain Washers.
ASA B27.2-1958. American Society of Mechanical Engineers, 29 W 39th St, New York 18. 8½ x 11, 10 pp. $1.

Lock Washers.
ASA B27.1-1958. American Society of Mechanical Engineers, 29 W 39th St, New York 18. 8½ x 11, 21 pp. $2.

Bibliography on Shell Molding—1952-58.
Engineering Societies Library, 29 W 39th St, New York 18. 8½ x 11, 27 pp. $2.

Study Abroad—Vol X
UNESCO Publications Center, 801 Third Ave, New York 22. 6 x 9½, 779 pp. $3.
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Statistical Quality Control: An Introduction for Management.
D H W Allan. Reinhold Publishing Corp, 430 Park Ave, New York 22. 5¼ x 7½, 129 pp. $3.50.

What's the Answer?—Brief Guide to Sources of Business Statistics.
Committee on Business Statistics, Chamber of Commerce of US, Washington 6, DC. 5½ x 8½, 34 pp. 50¢.

Materials Engineering Design for High Temperatures.
Edited by J Marin. Penn State University, University Park, Penna. 8½ x 11, 420 pp. $9.50.
Proceedings for short course.

Current Reprints

While the supply lasts, single copies of the following reprints are obtainable by using the Reader Service Card.

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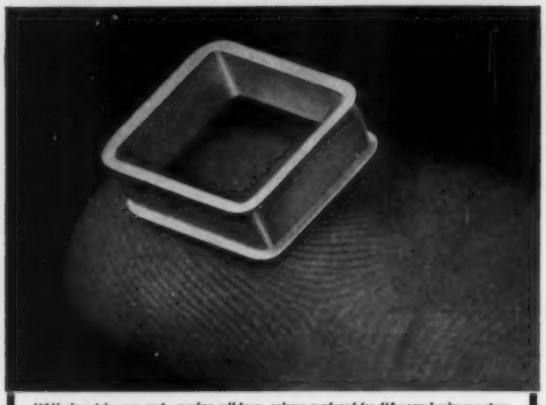

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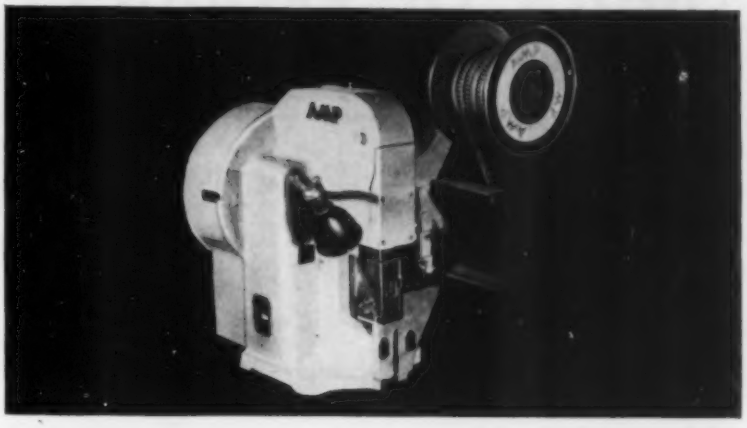

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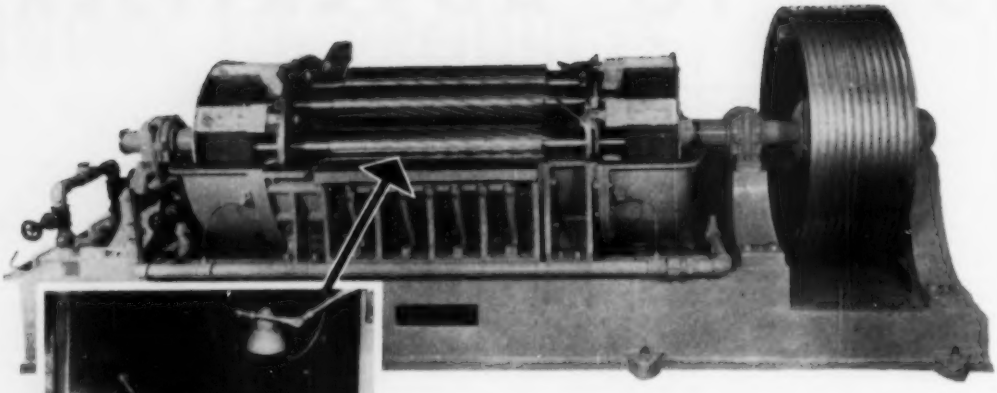

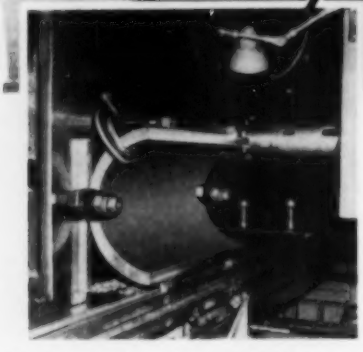

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ACIPCO

stainless steel liners

Size Range Lengths up to 410" have been produced to meet modern machinery requirements. OD's from 2.25" to 50"; wall thicknesses from .25" to 4"

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Reject recovery with Anton J. Haug refiners is saving paper mills more than $7 million per year in wood alone! ACIPCO *furnishes tough, durable, stainless steel liners which go inside the main casings of the machines.*

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ACIPCO plays an important part in reject recovery by furnishing the stainless steel lining which goes inside the main casing of the Haug refiner. The lining, statically cast to Haug's exacting specifications, fits inside a stationary cylindrical shell.

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Stainless steel, carbon steel, alloy iron or special analyses—versatile ACIPCO tubes are made to solve your specific tubular metal problem. Call ACIPCO today for complete information—or for expert technical assistance.

Special Products Division

AMERICAN

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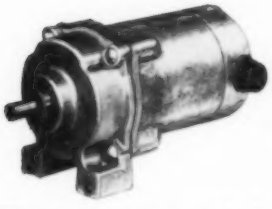
Matching Gearmotors

Three-stage gearmotor incorporates special brackets, reversing switch and connecting cord for pipe threader.



Differential planetary gear train allows for unusually compact design in miniature gearmotor for business machines.

Six-pole 400 cycle AC gearmotor for operating tap-changing switch.

Single-stage worm gearmotor. Rolled thread on output shaft actuates traveling nut.

NEW!

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- *low speed*
- *high torque*
- *compactness*
- *dependability*
- *low weight*
- *favorable cost*
- *improved product appearance*

Our manufacturing facilities enable us to build the complete range of sizes and types of hobbed and shaped gears for use with fractional horsepower motors.

Many years of specialized experience in this field, combined with the finest gear cutting and testing equipment, assure unexcelled performance in Lamb Electric gearmotors.

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SPECIAL APPLICATION FRACTIONAL HORSEPOWER **MOTORS**

CIRCLE 102 READER SERVICE CARD

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